NASA Contractor Report 178239

Application of Decomposition Techniques to the Preliminary Design of a Transport Aircraft

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Marietta, Georgia 30063

Contract NAS1 - 18068

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FOREWORD

Lockheed-Georgia Company recognizes the important role that advanced decomposition techniques for numerical optimization will play in the design of future aerospace systems. Examination of the impact of these techniques on aircraft preliminary design is highly topical for two reasons. First, progress in the development of a linear decomposition technique at NASA Langley has reached the point where a large-scale test of the formulation is required. Second, continually increasing emphasis on expanding the performance envelope, integrating more engineering specialties into the design process, and lowering development and support costs has made the use of design optimization more critical in the preliminary design phase. This final contract report contributes to the examination of the impact of linear decomposition on preliminary design by studying the formulation of a transport aircraft design problem.

This report is also identified by Lockheed report number LG86ER0092 for Lockheed internal control purposes.

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Summary

A nonlinear constrained optimization problem describing the preliminary design process for a transport aircraft has been formulated. A multifaceted decomposition of the optimization problem has been made. Flight dynamics, flexible aircraft loads and deformations, and preliminary structural design subproblems appear prominently in the decomposition. The use of design process decomposition for scheduling design projects, a new system integration approach to configuration control, and the application of object-centered programming to a new generation of design tools are discussed.

1. System Engineering in the Aircraft Design Process

Decomposition is a fundamental problem-solving technique of system engineering. The system hierarchy and functional decomposition are used in system definition and mission requirements analysis, requirements flowdown and allocation, and in the planning of system integration, interface management and trade studies (ref. 1). The system hierarchy and functional decompositions are arranged in levels. At each level, there is a correspondence between the subsystems appearing on the system hierarchy and the functional units appearing in the functional decompostion. The interfaces between the subsystems are defined by the functional decomposition.

At the lowest level of the system hierarchy, these interfaces are used to generate specifications for the functional units which make up the system. The functional units at the lowest level of the system hierarchy cannot be decomposed any further without forcing the designer to adopt a particular design solution. The components that make up system elements at the lowest level of the system hierarchy may perform more than one function. In some cases, several components making up a system element at the lowest level of the system hierarchy may be required to accomplish a single function. Although the system-subsystem-component decomposition and the functional decomposition can be carried down below this level, the one-to-one correspondence between them breaks down.

An aircraft-based transportation system is made up of bases and airfields, cargo, maintenance and support, training, and other elements. Considered as a part of such a transportation system, the transport aircraft itself is a functional unit at the lowest level of the system hierarchy. The aircraft functional unit can not be decomposed into components by the techniques of reference 1 without forcing the aircraft designer to adopt a particular design solution. This study is concerned with the aircraft functional unit of a transportation system and with decomposition techniques that are appropriate for aircraft design, as distinguished from system engineering.

The system-subsystem-component decomposition can be carried down into the aircraft system element. This is done by the Work Breakdown Structure (ref. 1). Part of this decomposition is shown in Figure 1 to illustrate

the idea that the continuation of the system hierarchy breaks the configuration into managable parts. The functions performed by the aircraft can also be decomposed, and Figure 2 shows part of the aircraft functional decomposition. Each of these functions corresponds to a design analysis discipline.

The system integration process of reference 1 cannot be carried down into the aircraft system elements because the functions in Figure 2 cannot be assigned to the components in Figure 1. For example, although the wing, fuselage, and empennage all have primary functions (develop lift, carry payload, and ensure static stability), they all have a "secondary" function: to support the structural loads encountered by the aircraft in flight. Of course, this function is not really "secondary": it is just as important as the components' primary functions.

System integration methodology along the lines of the reference 1 approach can be carried much further in the engineering design of avionics and software. In these disciplines, the system hierarchy and functional decompositions can be carried down to the level where the component elements can be developed by a single designer working alone. The design of an aircraft necessarily involves a larger team.

An extension of system integration methodology which could coordinate the efforts of the design team without interfering with design decisions would be a very valuable tool. The decomposition of the configuration (Figure 1) and of the design analysis (Figure 2) are fundamental to current aircraft design practice. The process aspect of design activity is equally important: system integration is a process.

This report is about decomposition of the process aspect of design. The design process decomposition defines the elements of the design process (design tasks or subproblems) and the interfaces between these elements. Since the design process is iterative, its decomposition must define how the iteration is to be performed. The design process decomposition is used to plan, schedule, and control the design effort to ensure that definite progress toward system integration goals is made at each step.

1.1 Models and Decomposition

The basic model for the configuration is geometry. Configuration geometry is essentially hierarchical. The system hierarchy provides a way to decompose the configuration that corresponds naturally to the geometric model. The functional aspects of a system are modeled by functional relationships among system parameters and requirements. Three equivalent models for these functional relationships are available (Figure 3): equations/inequalities, directed graphs, and the adjacency matrix of the directed graph (ref. 2). The n-squared matrix, used in System Engineering to represent the functional decomposition (ref. 1), is closely tied to the adjacency matrix model: the n-squared matrix imposes a block submatrix structure on the adjacency matrix. Blocks along the diagonal correspond to the functional units, and the off-diagonal blocks represent coupling

between functions.

In order to model the process aspects of the design activity, directed graph models such as task flow and PERT diagrams have been applied (ref. 1). Iterative loops are usually modeled explicitly on a task flow diagram. PERT handles iteration indirectly by allowing uncertainty in subtask completion times. Neither technique defines a controlling procedure for performing the iterations. Without a model of the controlling procedure, there is no way to distinguish a successful design process decomposition - one that rapidly converges system integration efforts on an optimal design - from a divergent design process that cannot produce a design meeting all system requirements at any cost.

Design optimization (refs. 3, 4, and 5) provides a model for control of the design process. Design optimization is the statement of a design problem as a nonlinear constrained optimization problem. Techniques for solving the nonlinear constrained optimization problem (ref. 6) can then be applied to find a solution to the original design problem. One form of the nonlinear constrained optimization problem is:

To minimize the objective function, $f(x)$,

Subject to the equality constraints,

$$h(x) - b = 0$$

and to the inequality constraints,

$$g(x) - c \leq 0$$

The design optimization model provides a definition for the procedure through which the three aspects of design activity interact. The configuration and functional aspects of design are given simple representations in the design optimization model. These simple representations emphasize interaction of the design configuration and function with the design process control. The configuration aspect of design is represented by a set of design variables or design parameters. Design synthesis is the result of interaction of the configuration and the design process. The design process interacts with the functional aspect of design through the application of engineering design analysis to evaluate the functional relationships. The iteration procedure is diagrammed in Figure 4.

As seen in Figure 4, an initial guess for the values of the design variables is evaluated by the design analysis. The evaluation of system performance as a function of the parametric configuration description corresponds to the objective function $f(x)$ and the equality and inequality constraint functions $h(x)$ and $g(x)$ of the nonlinear constrained optimization problem. The design analysis evaluations are compared with system requirements (represented by the vectors b and c of the constraints). Based on the sensitivity of the system performance to changes in the design variables/parameters, a new parametric design, $x + \Delta x$ is identified and the

process is iterated. A globally convergent algorithm (ref. 6) for solving the nonlinear constrained optimization problem is used in the design optimization model to identify a new parametric design and iterate the process.

Design optimization provides a model of the process aspects of design activity that is able to capture the idea of a convergent design process. The design process decomposition can be based on techniques that have been successfully applied to solve large design optimization problems (refs. 7 and 8). The work reported here is based on an iterative scheme for converging a network of design optimization subproblems developed by Sobieski (ref. 9). The technique is called linear decomposition. Sobieski and co-workers have suggested (ref. 10) that linear decomposition may be used to iterate through the system hierarchy, using reoptimization with optimal sensitivity constraints (refs. 9, 11) to resolve conflicting design requirements between system elements.

1.2 Scope of this work

This idea was investigated by formulating a significant portion of the aircraft preliminary design activity for a transport aircraft as a nonlinear constrained optimization problem. A combination of heuristics and experience was used to decompose this problem into a network of design optimization subproblems. (A heuristic is a "rule of thumb" used to find an approximate solution close to the correct one.) The decomposition specified how the design parameters were to be passed between the subproblems so that the Sobieski technique for iterating through the decomposition could be used. Following the approach in reference 10, a decomposition was sought that corresponded to the system hierarchy form: that is, a hierarchical (tree) structure in which each subproblem corresponds to a system element (such as a subsystem or a component.)

Fitting the subproblems into the system hierarchy form proved to be a difficult problem. The subproblems tended to be large and did not correspond well to the elements of the aircraft system hierarchy. The reason for this incompatibility is that the functional aspect of design is not reflected in the system hierarchy. For example, all the hardware components on the aircraft have mass, and, as a result, almost all of the aircraft system components are coupled with more than one system function. This suggests that the design process decomposition has its own form, distinct from the functional and system hierarchy decompositions.

The process of preliminary design for a transport aircraft has been decomposed into a multifaceted form. The multifaceted form reflects both the functional and system hierarchy decompositions. Significant advantages of the system hierarchy decompostion, such as parallel solution of design problems at the same level (ref. 10) are carried over into the multifaceted decomposition.

Results of the multifaceted design process decomposition for a transport aircraft are reported in Section 2. Section 3 examines the issues

involved in applying the multifaceted decomposition to system integration in preliminary design. The heuristics used to form the design process decomposition are found in Appendix A. Appendix B discusses the problem of divergence in the multifaceted decomposition and proposes a direction for further research. Appendix C describes the details of the linear decomposition formulation of two of the subproblems in the multifacted decomposition and discusses the iteration between them.

2. The Design Process Decomposition for a Transport Aircraft

The nonlinear programming formulation used to construct the design process decomposition does not attempt to completely describe the extremely complex process of aircraft preliminary design. The interaction of the aerodynamic, structural, propulsion, control, and, to a limited extent, operational aspects of a transport aircraft in determining a design with the minimum take-off gross weight is considered. Performance of a design mission (or missions) impacts the take-off gross weight through the weight of the fuel required to fly the mission. Take-off gross weight measures how efficiently alternative designs perform the design mission(s).

The size of a nonlinear programming problem can be measured by the sum of the number of design variables and the number of constraint and objective functions. This quantity is 470 for the part of the preliminary design process considered in this report. In developing this formulation, an initial set of design relationships was defined using references 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21. Questions and ambiguities concerning how the design relationships are applied in practice were resolved through discussions with aircraft designers and engineering analysis specialists. Some of the design relationships are based more heavily on the references, and some more heavily on discussions with engineers. The flight controls design relationships, for example, are based almost entirely on reference 15, while the approach to structural dynamics is based much more on conversations with structural dynamicists and landing gear designers.

Design relationships were included in the formulation if they determined a design quantitity that was explicitly constrained or was subject to different levels of approximation as iterations of the design process were made. Difficult choices were made in the case of the mass matrix for finite element analysis and the stability derivatives used in flight dynamics. These design quantities were not included in the final formulation.

The details of design criteria considered in the preliminary design of a transport aircraft differ considerably depending on the aircraft system specification. The analysis process is also configuration-dependent to some extent. Rather than attempting to advocate a particular analysis approach, the results presented in this report give a concise, accurate description of the interconnections between the preliminary design analyses.

The faithfulness of the representation of the design process offered here could be improved considerably through additional critique by expert analytical engineers and designers. However, while these improvements may alter the details of the design tasks, the multifaceted structure of the design process decomposition is determined by the interconnections between the physical and operational relationships which, along with the aircraft components, define the concept of a transport aircraft. These relationships will not be substantially changed by taking a different approach to the design analysis.

An interesting issue encountered in developing the formulation

involved finding a practical representation for the design relationships. Sobieski (ref. 10) originally stated the problem in terms of the adjacency matrix (Figure 3c). The signal flow graph representation (Figure 3b) provided the best means for describing how the decomposition heuristics should work. Both of these representations became increasingly difficult to use as additional design relationships were defined. The complexity of the signal flow graph and the size of the adjacency matrix (220,900 entries, most of which are zero) made it difficult to use these tools to convey useful information. The direct representation in terms of functional relationships (Figure 3a) provided the most practical means to present the completed formulation.

2.1 Subproblems of the Design Process Decomposition

The 470 design relationships were decomposed into 144 subproblems using the technique described in Appendix A. The overall form of the design process decomposition can be seen in Figure 5. Design tasks were assigned to each subproblem based on the design relationships in the subproblem and on the interfaces to other subproblems. Table 1 lists the design tasks assigned to each of the subproblems in Figure 5. The design relationships in each of the subproblems and the interfaces between the subproblems are detailed in Tables 4 through 291. A discussion of the formulation of the subproblems as nonlinear programming problems and their solution using linear decomposition is presented in Appendix C.

2.2 Features of the Decomposition

Lines connecting the subproblems in Figure 5 indicate parameter flows between the subproblems. Examining the form of the design process decomposition in Figure 5, three pivotal design tasks are prominent. Lines representing parameter flows are seen to converge on and radiate from subproblems 4-08, 5-14, and 6-06. From Table 1, these subproblems correspond to (a) the flight dynamics problem (subproblem 4-08), (b) the flexible aircraft maneuvering shapes and loads problem (subproblem 5-14) and (c) the preliminary structural design problem (subproblem 6-06). The central importance of these design tasks in the multifaceted decomposition is confirmed by an examination of Tables 4 through 291. Subproblem 4-08 involves 50 design relationships, 30 input parameters, and 59 output parameters; subproblem 5-14 involves 102 design relationships, 98 input parameters, and 150 output parameters; and subproblem 6-06 involves 88 design relationships, 71 input parameters, and 116 output parameters. Reference 22 describes an integrated design system for determining flexible aircraft loads and bringing this information into the structural design process. The number of other design tasks which interface with these problems in the design process decomposition emphasizes the importance of such a design tool. Similar integrated design capability is needed to address the flight dynamics problem.

The results suggest that there are varying roles for the subproblems of the decomposition. Consider, for example, subproblem 3-05. Subproblem 3-05 provides a consistent value for the low-speed-drag-polar parameter to

the other subproblems. Other subproblems (e.g., 4-08, 5-14, and 6-06) seem to take a more active role in altering the configuration in response to design requirements.

The nature of the parameters that are passed between subproblems raises several problems. The design relationships were defined in terms of objects, such as the cruise 3-d shape, that are used in the design process. These objects are passed back and forth between subproblems as "parameters" in the multifaceted decomposition. The optimal sensitivity derivatives are defined in reference 11 only for real-valued parameters. Further research is required to develop techniques to handle more general types of "parameters". For example: the **cruise-3d-shape** parameter must be passed between subproblems 4-08 and 5-14 (Table 65). How are optimal sensitivites to be computed for a design quantity representing the aircraft's shape? Recent results in shape optimization (ref. 23) and shape design sensitivity analysis (ref. 24) may prove useful in addressing this issue.

The **fuselage-structural-arrangement** is passed as a parameter between subproblems 4-09 and 5-14. The structural arrangement specifies the type and location of structural elements and the joints connecting them. The discrete nature of the **fuselage-structural-arrangement** design relationship indicates that development of some heuristics for determining optimal sensitivites for discrete parameters is important. The work of Schmit and Fleury (ref. 25) suggests that duality theory can be applied to address this problem.

Subproblems 7-4 through 7-51 are responsible for ensuring that the elastic properties of the individual structural elements are adequate for satisfaction of the stress constraints. In the past, when material selection was limited (i.e., to aluminum and similar metals), there was little freedom of design in meeting these constraints. However, increased use of composite materials and the accompanying ability to tailor the design of structural elements to very specific stress conditions will greatly expand the importance of these tasks within the design process. The decomposition structure illustrates the key role of these subproblems and the impact of structural element design techniques on the design process as a whole.

3. Impact on Aircraft Design

The design process decomposition promises to be very useful for aircraft preliminary design. The decomposition can be used for planning and scheduling. An interesting approach to configuration control is suggested by the way the design process decomposition seems to manage many different configurations. The design process decomposition technique will be an important component of a new generation of object-centered design tools currently being developed.

3.1 Scheduling of Design Tasks

The subproblems in the design process decomposition can be interpreted as design tasks. Each of the design tasks is iterative, and will have to be performed several times during the preliminary design effort. The design task will take a certain amount of work each time. In planning the design effort, project managers and design engineers will have to make some estimate of the number of times each task will be iterated. Once the length of time and the number of iterations for each task has been estimated, the design process decomposition can be used to develop a project schedule, identify configuration release milestones, and plan trade studies.

3.2 Configuration Control

Ever-increasing design definition is required throughout the design process in order to thoroughly explore alternative design solutions. Paradoxically, the investment in developing this design definition tends to limit the designers' freedom to subsequently change the design (ref. 10). A closely related and recurring situation in aircraft design is the difficulty of getting all of the design task groups to analyze the same configuration. The solution has traditionally been "better configuration control". In order to control the configuration, we have to know what it is. The problem is that by the time we know what the configuration is, it is already designed.

The design process decomposition suggests another way of doing things: decentralize the configuration control and concentrate management on the interfaces. The design process decomposition clearly models the existence of many different configurations. The system integration process converges these configurations on a single, optimal configuration.

3.3 Design Applications of Object-Oriented Programming

In developing computer models of design activity, it is particularly appropriate to model the design configuration and its components and sub-components using object-oriented programming techniques (ref. 26). Representing design components as software objects allows associated computer programs to manipulate the components and their attributes (e.g., dimensions, mass, etc.) in much the same way the designer would. Design activities may then be directly implemented in terms of actions and responses to be associated with these software objects, thereby modelling the relevant physical behavior of the design components (ref. 27).

Analysis of the design configuration can also be modelled using the object-oriented approach. Insofar as analysis consists of the application of appropriate design functions to calculate values for the design variables (e.g., component attributes), analysis programs may be thought of as "analytical model" objects which manipulate both design function and design variable objects (ref. 28).

Finally, the present work serves to demonstrate the applicability of object-oriented programming to computer models of the process aspect of design activity. The decomposition heuristics described in Appendix A are implemented as acting on subproblem (i.e., task) objects, between which the transfer of parameters and optimal sensitivity derivatives takes place.

Combining an object-oriented representation of the configuration ("components"), an object-oriented representation of the analysis ("models"), and an appropriate technique for both numeric and symbolic constraint propagation (see ref. 29), it should be possible to develop a computer representation of the vehicle under design which provides the ability to quickly implement and investigate design changes, and readily maintain a consistent configuration, as desired. Combining these capabilities with an object-oriented model of the design process (to include sub-problem managers, optimization handlers, documentation facilities, and the like) could result in a system which could manage the design problem from conceptual design through the final stages of advanced preliminary design.

Appendix A. Decomposition Heuristics

The design process decomposition was constructed by applying two heuristic rules to the subproblems. The method is related to techniques for resolving the structure of complex systems described in references 30, 31, 32, and 33. The heuristics build up the decomposition from the design relationships by coupling connected subproblems. Subproblems are coupled if design parameters that are set in one of the subproblems are inputs to a design relationship in another.

The decomposition procedure first defines a subproblem for each of the design relationships. One of the design relationships is identified as the objective function for the optimization problem.

The first heuristic defines the levels of the design process decomposition. The subproblem containing the objective design relationship is placed at level 0. The rest of the levels are computed by iteration as shown in Figure 6. Subproblems are placed at level (i + 1) if they are coupled to subproblems at level (i), but not coupled to any subproblems at a level above (i.e., with a numerically smaller level index) level (i).

The second heuristic merges coupled subproblems that are on the same level of the design process decomposition (Figure 7).

Appendix B. Iteration through the Multifaceted Design Process Decomposition

The system hierarchy decomposition has definite advantages for iteration. The system hierarchy network has a special structure, called a "tree" in graph theory. The tree structure of the system hierarchy implies that once subproblems are decoupled, they remain decoupled at all subsequent levels of the system hierarchy. This fact makes it relatively simple to define how the design parameters and optimal sensitivity derivatives are to be passed from one subproblem to another. As shown in Figure 8, (ref. 10), parameters flow top-down and optimal sensitivity derivatives flow bottom-up.

The multifaceted decomposition captures the functional form of the design and thus is more appropriate for the design process decomposition than the system hierarchy. However, iteration through the multifaceted decomposition is necessarily more complex than iteration through the system hierarchy. The form of the multifaceted decomposition is shown in Figure 9. Subproblems typically have more than one predecessor at a higher level in the multifaceted decomposition (e.g subproblem 5-14 in Figure 5.)

Divergence in the Multifaceted Decomposition

The top-down parameter flow/bottom-up sensitivity flow scheme of Figure 8 is potentially divergent if applied to the multifaceted decomposition. Consider the situation shown in Figure 10. Subproblem 3 has two predecessors, subproblem 1 and subproblem 2. A value for parameter 1 is set by an optimal solution of subproblem 1 and passed to subproblem 3. Parameter 2 is set by an optimal solution of subproblem 2 and is also passed to subproblem 3. A optimal solution to subproblem 3 is found and its sensitivity to variation of parameters 1 and 2 is calculated using the technique of reference 11. The optimal sensitivity derivative with respect to parameter 1 is passed back up from subproblem 3 to subproblem 1, and similarly for parameter 2. Subproblems 1 and 2 are resolved subject to the optimal sensitivity constraints. A possible outcome of the re-solutions is shown in Figure 11.

In Figure 11, the results of line searches in subproblems 1 and 2 are superimposed on the level curves of the optimal solution (penalty function) of subproblem 3. The subproblem 1 line search is performed by varying parameter 1 with the value of parameter 2 held fixed. Point C is found to be optimum. Point B is the subproblem 2 optimum. The new values of parameters 1 and 2 that will be passed to subproblem 3 in the next iteration correspond to point D. But point D results in a lower value of the subproblem 3 optimal solution penalty function than point A. The iteration is divergent.

Proposed Iteration Procedure for the Multifaceted Decomposition

Reference 9 considers more general iteration strategies than the Figure 8 procedure proposed in reference 10. An alternative to the top-down parameter flow/bottom-up sensitivity flow strategy can be developed based on the reference 9 iteration techniques. Divergence in the multifaceted

decomposition example (Figure 11) is caused by the fact that the optimizations in parameters 1 and 2 are not coordinated. Coordination of these optimizations can be achieved by including them both in the same subproblem. In order to do this, the parameter and sensitivity flows must be inverted in some cases, as shown in Figure 12.

This inversion may still result in divergence. The bottom-up parameter flow/top-down sensitivity flow iteration strategy can diverge when it is applied to subproblems with more than one successor. This is because when the parameter and sensitivity flows are reversed, as in the bottom-up parameter flow/top-down sensitivity flow iteration strategy, the roles of predecessor and successor are switched. Thus, applying the bottom-up parameter flow/top-down sensitivity flow in the case where a subproblem has more than one successor is completely analogous, from the standpoint of the divergence phenomenon, to the application of the top-down parameter flow/bottom-up sensitivity flow in the case of a subproblem with more than one predecessor. Thus, to avoid divergence, some parameters will have to be passed both ways (Figure 12). Conflicts between the parameter values can then be resolved by constraining them to be equal in both subproblems (Reference 9). Whether this technique is actually convergent has not yet been established and requires further investigation.

Appendix C. Formulation of Nonlinear Programming Problems in the Multifaceted Decomposition

The formulation of subproblem 1-01 of Table 1, take-off weight allocation, as a nonlinear programming problem is given in Table 2. The constraints in subproblem 1-01 are of two types: design relationship and optimal sensitivity. Design relationships in subproblem 1-01 are listed in Table 4. The design relationship constraint, constraint (1) of Table 2, equates the take-off-gross-weight design parameter to a function of the mission-fuel and empty-weight design parameters. (Explicitly, this function would be:

take-off-gross-weight = mission-fuel + empty-weight

+ trapped fuel, etc.)

The decision variables of this nonlinear programming problem are take-off-gross-weight, mission-fuel, and empty-weight.

Applying the linear decomposition technique for iterating through the subproblem network, an initial solution for subproblem 1-01 consists of an allocation of take-off-gross-weight to mission-fuel and empty-weight so that constraint (1) of Table 2 is satisfied. The initial allocation would be based on an examination of weight data for similar aircraft, and would not involve application of any numerical optimization techniques.

The interfaces between subproblem 1-01 and subproblems at level 2 of the multifaceted decomposition are listed in Table 5. Table 3 gives the nonlinear programming formulation for one of these subproblems, subproblem 2-04. The initial solution for subproblem 2-04 involves finding a combination of trimmed-drag-polar, f-x-t (thrust in the direction of the flight path), and specific-fuel-consumption satisfying constraint (1) of Table 3. take-off-gross-weight and mission-fuel are held fixed at the values determined by subproblem 1-01. Partial deriviatives of a penalty function, K, measuring how successful we were in satisfying constraint (1) of Table 3 are passed to subproblem 1-01 on level 1. These partial derivatives are taken with respect to take-off-gross-weight and mission-fuel, with the trimmed-drag-polar, f-x-t, and specific-fuel-consumption design quantities adjusted to maintain the optimal value of the penalty function (using the technique of Reference 11).

The optimal sensitivity constraints, (2) through (6) of Table 2, are included in the second and subsequent iterations re-solving subproblem 1-01. These constraints force subproblem 1-01 to adjust the take-off-gross-weight allocation to improve the feasiblity of the solutions to the level 2 subproblems. For example, constraint (5) of Table 2 requires that any adjustments to the take-off-gross-weight allocation will not adversely affect the aircraft's ability to perform the design mission.

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Table 1.
Design Tasks of the Multifaceted Design Process Decomposition.

Subproblem	Design Task
1-01	take-off weight allocation
2-01	balanced field take-off acceleration and climb gradient
2-02	take-off stall speed
2-03	nose wheel lift-off
2-04	mission performance
2-05	empty weight allocation
3-01	tire/runway friction coeff.
3-02	thrust vector
3-03	take-off (C-L)max
3-04	braking effective thrust
3-05	low speed drag polar
3-06	main gear location
3-07	balanced-field takeoff distance
3-08	landing gross weight
3-09	horizontal tail (C-L)max
3-10	wing/body aerodynamic center
3-11	wing/body moment coefficient
3-12	aircraft c.g. location, sizing of the horizontal tail
3-13	trimmed flight drag polar
3-14	specific fuel consumption
3-15	flight design gross weight
3-16	structural weight allocation
3-17	control system weight

Table 1., cont.

4-01	landing stall speed
4-02	landing descent gradient
4-03	nose gear braking loads
4-04	adjusted tire/runway friction coefficient (take-off)
4-05	landing brake deceleration
4-06	landing equivalent inertia time
4-07	main gear landing impact loads
4-08	flight dynamics
4-09	fuselage c.g. location
4-10	horizontal tail c.g. location
4-11	vertical tail c.g. location
4-12	wing c.g. location
4-13	main gear c.g. location
4-14	nose gear c.g. location
4-15	fuselage structural weight
4-16	main gear structural weight
4-17	wing structural weight
4-18	rudder actuator weight
4-19	horizontal tail structural weight
4-20	aileron actuator weight
4-21	elevator actuator weight
4-22	vertical tail structural weight
4-23	nose gear structural weight

Table 1., cont.

5-01	landing speeds, distances
5-02	landing flap settings
5-03	nose gear attachment loads
5-04	wing/body angle-of-attack lift derivative
5-05	engine installation losses
5-06	airplane angle-of-attack lift and pitching moment derivatives
5-07	horizontal tail angle-of-attack lift derivative
5-08	engine support structure aerodynamics loads
5-09	fuselage aerodynamic loads
5-10	horizontal tail aerodynamic loads
5-11	vertical tail aerodynamic loads
5-12	pull-up angle of attack
5-13	vertical tail location
5-14	flexible aircraft loads, deformations
5-15	horizontal tail location
5-16	pull-up elevator deflection
5-17	airplane moments of inertia
5-18	elevator quasi-static aerodynamic loads
5-19	nose gear geometry

Table 1., cont.

6-01	landing distance
6-02	engine inlet pressure recovery
6-03	engine inlet distortion
6-04	engine ram drag
6-05	engine boattail drag
6-06	preliminary structural design
6-07	rudder actuator flutter analysis
6-08	rudder maximum hinge moment
6-09	flutter deformations
6-10	nose gear kinematics
6-11	wing structural arrangement
6-12	vertical tail moments of inertia
6-13	main gear moments of inertia
6-14	fuselage moments of inertia
6-15	wing moments of inertia
6-16	horizontal tail moments of inertia
6-17	nose gear moments of inertia
6-18	load factor determination
6-19	main gear kinematics
6-20	elevator actuator flutter analysis
6-21	aileron actuator flutter analysis
6-22	aileron maximum hinge moment
6-23	aircraft quasi-steady aerodynamic loads (landing)
6-24	wing center-of-pressure distribution
7-01	inlet-3d-geometry
7-02	fuselage aerodynamic loads (pull-up)
7-03	horizontal tail aerodynamic loads (pull-up)
7-04	vertical tail aerodynamic loads (pull-up)
7-05 - 7-52	structural element stresses
7-53	fuselage aerodynamic loads (turn)
7-54	horizontal tail aerodynamic loads (turn)
7-55	vertical tail aerodynamic loads (turn)

Table 2. Formulation of Subproblem 1-01 as a Nonlinear Programming Problem.

Minimize: take-off-gross-weight

Subject to Constraints:

take-off-gross-weight = f1(mission-fuel,empty-weight) (1)

K(2-01)(take-off-gross-weight) $\leq$ K*(2-01) (2)

K(2-02)(take-off-gross-weight) $\leq$ K*(2-02) (3)

K(2-03)(take-off-gross-weight) $\leq$ K*(2-03) (4)

K(2-04)(take-off-gross-weight,mission-fuel) $\leq$ K*(2-04) (5)

K(2-05)(empty-weight) $\leq$ K*(2-05) (6)

Decision Variables:

take-off-gross-weight, mission-fuel, empty-weight

Table 3. Formulation of Subproblem 2-04 as a Nonlinear Programming Problem.

Find a Feasible Solution to:

mission-fuel (1-01) = f2(trimmed-drag-polar, f-x-t,
specific-fuel-consumption,
take-off-gross-weight (1-01)) (1)

$K(3\text{-}02)(f\text{-}x\text{-}t) \leq K^*(3\text{-}02)$ (2)

$K(3\text{-}13)(\text{trimmed-drag-polar}) \leq K^*(3\text{-}13)$ (3)

$K(3\text{-}14)(\text{specific-fuel-consumption}) \leq K^*(3\text{-}14)$ (4)

f-x-t = f-x-t (3-02) (5)

Decision Variables:

trimmed-drag-polar, f-x-t, specific-fuel-consumption

Table 4. Design Relationships in Subproblem 1-01

take-off-gross-weight is a function of:

mission-fuel
empty-weight

Table 5. Subproblem 1-01 Interfaces

SUCCESSORS

Input Parameters To Subproblem 2-03

take-off-gross-weight

Input Parameters To Subproblem 2-04

take-off-gross-weight
mission-fuel

Input Parameters To Subproblem 2-01

take-off-gross-weight

Input Parameters To Subproblem 2-02

take-off-gross-weight

Input Parameters To Subproblem 2-05

empty-weight

Table 6. Design Relationships in Subproblem 2-01

take-off-brake-deceleration is a function of:

- take-off-gross-weight
- braking-effective-thrust
- decision-speed
- low-speed-drag-polar

take-off-distance-to-failure is a function of:

- decision-speed
- f-x-t
- thrust-line
- low-speed-drag-polar
- take-off-gross-weight
- tire/runway-friction-coefficient

take-off-equivalent-climb-gradient is a function of:

- engine-out-f-x-t
- thrust-line
- low-speed-drag-polar
- take-off-gross-weight
- take-off-distance-from-failure-to-screen-height

take-off-equivalent-inertia-time is a function of:

- decision-speed
- take-off-gross-weight
- engine-out-f-x-t
- thrust-line

Table 7. Subproblem 2-01 Interfaces

PREDECESSORS

Output Parameters To Subproblem 1-01

take-off-gross-weight

SUCCESSORS

Input Parameters To Subproblem 3-07

take-off-equivalent-inertia-time
take-off-equivalent-climb-gradient
take-off-distance-to-failure
take-off-distance-from-failure-to-screen-height
decision-speed
take-off-brake-deceleration

Output Parameters To Subproblem 3-07

take-off-equivalent-inertia-time
take-off-equivalent-climb-gradient
take-off-distance-to-failure
take-off-distance-from-failure-to-screen-height
decision-speed
take-off-brake-deceleration

Input Parameters To Subproblem 3-04

braking-effective-thrust

Input Parameters To Subproblem 3-05

low-speed-drag-polar

Output Parameters To Subproblem 3-05

low-speed-drag-polar

Table 7. Subproblem 2-01 Interfaces, cont.

Input Parameters To Subproblem 3-02

engine-out-f-x-t
f-x-t
thrust-line

Output Parameters To Subproblem 3-02

engine-out-f-x-t
f-x-t
thrust-line

Input Parameters To Subproblem 3-01

tire/runway-friction-coefficient

Table 8. Design Relationships in Subproblem 2-02

v-stall-take-off is a function of:

take-off-gross-weight
take-off-c-l-max

Table 9. Subproblem 2-02 Interfaces

PREDECESSORS

Output Parameters To Subproblem 1-01

take-off-gross-weight

SUCCESSORS

Input Parameters To Subproblem 3-07

v-stall-take-off

Table 9. Subproblem 2-02 Interfaces, cont.

Output Parameters To Subproblem 3-07

v-stall-take-off

Input Parameters To Subproblem 3-03

take-off-c-l-max

Table 10. Design Relationships in Subproblem 2-03

nose-wheel-lift-off is a function of:

horizontal-area
f-x-t
thrust-line
low-speed-drag-polar
airplane-cg
main-landing-gear-location
c-m-wing-body-ac
wing-body-ac
v-take-off-rotation
take-off-gross-weight
horizontal-c-l-max
horizontal-tail-volume-coefficient

Table 11. Subproblem 2-03 Interfaces

PREDECESSORS

Output Parameters To Subproblem 1-01

take-off-gross-weight

Table 11. Subproblem 2-03 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 3-12

airplane-cg
horizontal-tail-volume-coefficient
horizontal-area

Input Parameters To Subproblem 3-02

f-x-t
thrust-line

Output Parameters To Subproblem 3-02

f-x-t
thrust-line

Input Parameters To Subproblem 3-05

low-speed-drag-polar

Output Parameters To Subproblem 3-05

low-speed-drag-polar

Input Parameters To Subproblem 3-06

main-landing-gear-location

Input Parameters To Subproblem 3-11

c-m-wing-body-ac

Input Parameters To Subproblem 3-10

wing-body-ac

Input Parameters To Subproblem 3-07

v-take-off-rotation

Output Parameters To Subproblem 3-07

v-take-off-rotation

Table 11. Subproblem 2-03 Interfaces, cont.

Input Parameters To Subproblem 3-09

horizontal-c-l-max

Table 12. Design Relationships in Subproblem 2-04

mission-fuel is a function of:

trimmed-drag-polar
f-x-t
specific-fuel-consumption
take-off-gross-weight

Table 13. Subproblem 2-04 Interfaces

PREDECESSORS

Output Parameters To Subproblem 1-01

take-off-gross-weight
mission-fuel

SUCCESSORS

Input Parameters To Subproblem 3-13

trimmed-drag-polar

Input Parameters To Subproblem 3-02

f-x-t

Output Parameters To Subproblem 3-02

f-x-t

Table 13. Subproblem 2-04 Interfaces, cont.

Input Parameters To Subproblem 3-14

specific-fuel-consumption

Table 14. Design Relationships in Subproblem 2-05

empty-weight is a function of:

structural-weight
control-system-weight

Table 15. Subproblem 2-05 Interfaces

PREDECESSORS

Output Parameters To Subproblem 1-01

empty-weight

SUCCESSORS

Input Parameters To Subproblem 3-15

empty-weight

Input Parameters To Subproblem 3-08

empty-weight

Input Parameters To Subproblem 3-16

structural-weight

Input Parameters To Subproblem 3-17

control-system-weight

Table 16. Design Relationships in Subproblem 3-01

tire/runway-friction-coefficient is an independent design parameter

Table 17. Subproblem 3-01 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-01

tire/runway-friction-coefficient

SUCCESSORS

Output Parameters To Subproblem 4-04

tire/runway-friction-coefficient

Table 18. Design Relationships in Subproblem 3-02

thrust-line is an independent design parameter

f-x-t is a function of:

thrust-line
engine-net-thrust

engine-out-f-x-t is a function of:

f-x-t

Table 19. Subproblem 3-02 Interfaces

PREDECESSORS

Input Parameters To Subproblem 2-03

f-x-t
thrust-line

Output Parameters To Subproblem 2-03

f-x-t
thrust-line

Input Parameters To Subproblem 2-01

f-x-t
thrust-line
engine-out-f-x-t

Output Parameters To Subproblem 2-01

f-x-t
thrust-line
engine-out-f-x-t

Input Parameters To Subproblem 2-04

f-x-t

Output Parameters To Subproblem 2-04

f-x-t

SUCCESSORS

Input Parameters To Subproblem 4-08

thrust-line
engine-net-thrust

Table 19. Subproblem 3-02 Interfaces, cont.

Output Parameters To Subproblem 4-08

thrust-line
engine-net-thrust

Input Parameters To Subproblem 4-02

f-x-t
thrust-line

Output Parameters To Subproblem 4-02

f-x-t
thrust-line

Input Parameters To Subproblem 4-06

f-x-t
thrust-line

Output Parameters To Subproblem 4-06

f-x-t
thrust-line

Table 20. Design Relationships in Subproblem 3-03

take-off-c-l-max is a function of:

take-off-3d-shape

Table 21. Subproblem 3-03 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-02

take-off-c-l-max

SUCCESSORS

Input Parameters To Subproblem 4-04

take-off-c-l-max

Output Parameters To Subproblem 4-04

take-off-c-l-max

Input Parameters To Subproblem 4-08

take-off-3d-shape

Output Parameters To Subproblem 4-08

take-off-3d-shape

Table 22. Design Relationships in Subproblem 3-04

braking-effective-thrust is an independent design parameter

Table 23. Subproblem 3-04 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-01

braking-effective-thrust

SUCCESSORS

Input Parameters To Subproblem 4-05

braking-effective-thrust

Output Parameters To Subproblem 4-05

braking-effective-thrust

Input Parameters To Subproblem 4-03

braking-effective-thrust

Output Parameters To Subproblem 4-03

braking-effective-thrust

Table 24. Design Relationships in Subproblem 3-05

low-speed-drag-polar is a function of:

cruise-3d-shape
high-lift-device-3d-geometry

Table 25. Subproblem 3-05 Interfaces

PREDECESSORS

Input Parameters To Subproblem 2-03

low-speed-drag-polar

Output Parameters To Subproblem 2-03

low-speed-drag-polar

Input Parameters To Subproblem 2-01

low-speed-drag-polar

Output Parameters To Subproblem 2-01

low-speed-drag-polar

SUCCESSORS

Input Parameters To Subproblem 4-04

low-speed-drag-polar

Output Parameters To Subproblem 4-04

low-speed-drag-polar

Input Parameters To Subproblem 4-05

low-speed-drag-polar

Output Parameters To Subproblem 4-05

low-speed-drag-polar

Input Parameters To Subproblem 4-02

low-speed-drag-polar

Table 25. Subproblem 3-05 Interfaces, cont.

Output Parameters To Subproblem 4-02

low-speed-drag-polar

Input Parameters To Subproblem 4-08

high-lift-device-3d-geometry
cruise-3d-shape

Output Parameters To Subproblem 4-08

high-lift-device-3d-geometry
cruise-3d-shape

Table 26. Design Relationships in Subproblem 3-06

main-landing-gear-location is an independent design parameter

Table 27. Subproblem 3-06 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-03

main-landing-gear-location

SUCCESSORS

Output Parameters To Subproblem 4-03

main-landing-gear-location

Table 28. Design Relationships in Subproblem 3-07

decision-speed is a function of:

take-off-distance-from-failure-to-screen-height
take-off-distance-from-failure-to-stop

take-off-distance-from-failure-to-screen-height is a function of:

decision-speed
take-off-equivalent-climb-gradient

take-off-distance-from-failure-to-stop is a function of:

decision-speed
take-off-brake-deceleration
take-off-equivalent-inertia-time

v-take-off-rotation is a function of:

decision-speed
v-stall-take-off

balanced-field-takeoff-distance is a function of:

take-off-distance-to-failure
take-off-distance-from-failure-to-screen-height

Table 29. Subproblem 3-07 Interfaces

PREDECESSORS

Input Parameters To Subproblem 2-01

decision-speed
take-off-brake-deceleration
take-off-distance-to-failure
take-off-equivalent-climb-gradient
take-off-distance-from-failure-to-screen-height
take-off-equivalent-inertia-time

Output Parameters To Subproblem 2-01

decision-speed
take-off-brake-deceleration
take-off-distance-to-failure
take-off-equivalent-climb-gradient
take-off-distance-from-failure-to-screen-height
take-off-equivalent-inertia-time

Input Parameters To Subproblem 2-03

v-take-off-rotation

Output Parameters To Subproblem 2-03

v-take-off-rotation

Input Parameters To Subproblem 2-02

v-stall-take-off

Output Parameters To Subproblem 2-02

v-stall-take-off

Table 30. Design Relationships in Subproblem 3-08

landing-gross-weight is a function of:

empty-weight

Table 31. Subproblem 3-08 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-05

empty-weight

SUCCESSORS

Input Parameters To Subproblem 4-05

landing-gross-weight

Output Parameters To Subproblem 4-05

landing-gross-weight

Input Parameters To Subproblem 4-01

landing-gross-weight

Input Parameters To Subproblem 4-02

landing-gross-weight

Output Parameters To Subproblem 4-02

landing-gross-weight

Input Parameters To Subproblem 4-06

landing-gross-weight

Table 31. Subproblem 3-08 Interfaces, cont.

Output Parameters To Subproblem 4-06

landing-gross-weight

Input Parameters To Subproblem 4-07

landing-gross-weight

Table 32. Design Relationships in Subproblem 3-09

horizontal-c-l-max is a function of:

horizontal-3d-shape

Table 33. Subproblem 3-09 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-03

horizontal-c-l-max

SUCCESSORS

Output Parameters To Subproblem 4-08

horizontal-3d-shape

Table 34. Design Relationships in Subproblem 3-10

wing-body-ac is a function of:

wing-fuselage-3d-shape

Table 35. Subproblem 3-10 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-03

wing-body-ac

SUCCESSORS

Output Parameters To Subproblem 4-08

wing-body-ac
wing-fuselage-3d-shape

Table 36. Design Relationships in Subproblem 3-11

c-m-wing-body-ac is a function of:

wing-fuselage-3d-shape

Table 37. Subproblem 3-11 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-03

c-m-wing-body-ac

SUCCESSORS

Output Parameters To Subproblem 4-08

wing-fuselage-3d-shape

Table 38. Design Relationships in Subproblem 3-12

horizontal-area is an independent design parameter

horizontal-tail-volume-coefficient is a function of:

horizontal-area
airplane-cg
horizontal-ac

airplane-cg is a function of:

fuselage-cg
horizontal-cg
vertical-cg
wing-cg
main-landing-gear-cg
nose-landing-gear-cg

Table 39. Subproblem 3-12 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-03

airplane-cg
horizontal-tail-volume-coefficient
horizontal-area

SUCCESSORS

Input Parameters To Subproblem 4-08

airplane-cg
horizontal-area
horizontal-ac

Output Parameters To Subproblem 4-08

airplane-cg
horizontal-area
horizontal-ac

Input Parameters To Subproblem 4-09

fuselage-cg

Input Parameters To Subproblem 4-10

horizontal-cg

Input Parameters To Subproblem 4-11

vertical-cg

Input Parameters To Subproblem 4-12

wing-cg

Input Parameters To Subproblem 4-13

main-landing-gear-cg

Table 39. Subproblem 3-12 Interfaces, cont.

Input Parameters To Subproblem 4-14

nose-landing-gear-cg

Table 40. Design Relationships in Subproblem 3-13

trimmed-drag-polar is a function of:

trimmed-airplane-alpha
elevator-3d-geometry
trimmed-delta-e
cruise-3d-shape

Table 41. Subproblem 3-13 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-04

trimmed-drag-polar

SUCCESSORS

Output Parameters To Subproblem 4-08

trimmed-drag-polar
elevator-3d-geometry
cruise-3d-shape
trimmed-delta-e
trimmed-airplane-alpha

Table 42. Design Relationships in Subproblem 3-14

specific-fuel-consumption is a function of:

engine-net-thrust

Table 43. Subproblem 3-14 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-04

specific-fuel-consumption

SUCCESSORS

Output Parameters To Subproblem 4-08

engine-net-thrust

Table 44. Design Relationships in Subproblem 3-15

flight-design-gross-weight is a function of:

empty-weight

Table 45. Subproblem 3-15 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-05

empty-weight

SUCCESSORS

Output Parameters To Subproblem 4-08

flight-design-gross-weight

Table 46. Design Relationships in Subproblem 3-16

structural-weight is a function of:

main-landing-gear-structural-weight
nose-landing-gear-structural-weight
wing-structural-weight
fuselage-structural-weight
vertical-structural-weight
nacelle-pylon-structural-weight
horizontal-structural-weight

Table 47. Subproblem 3-16 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-05

structural-weight

Table 47. Subproblem 3-16 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 4-16

main-landing-gear-structural-weight

Input Parameters To Subproblem 4-23

nose-landing-gear-structural-weight

Input Parameters To Subproblem 4-17

wing-structural-weight

Input Parameters To Subproblem 4-15

fuselage-structural-weight

Input Parameters To Subproblem 4-22

vertical-structural-weight

Input Parameters To Subproblem 4-08

nacelle-pylon-structural-weight

Output Parameters To Subproblem 4-08

nacelle-pylon-structural-weight

Input Parameters To Subproblem 4-19

horizontal-structural-weight

Table 48. Design Relationships in Subproblem 3-17

control-system-weight is a function of:

elevator-actuator-weight
aileron-actuator-weight
rudder-actuator-weight

Table 49. Subproblem 3-17 Interfaces

PREDECESSORS

Output Parameters To Subproblem 2-05

control-system-weight

SUCCESSORS

Input Parameters To Subproblem 4-21

elevator-actuator-weight

Input Parameters To Subproblem 4-20

aileron-actuator-weight

Input Parameters To Subproblem 4-18

rudder-actuator-weight

Table 50. Design Relationships in Subproblem 4-01

v-stall-landing is a function of:

landing-gross-weight
landing-c-l-max

Table 51. Subproblem 4-01 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-08

landing-gross-weight

SUCCESSORS

Input Parameters To Subproblem 5-01

v-stall-landing

Output Parameters To Subproblem 5-01

v-stall-landing

Input Parameters To Subproblem 5-02

landing-c-l-max

Output Parameters To Subproblem 5-02

landing-c-l-max

Table 52. Design Relationships in Subproblem 4-02

landing-descent-gradient is a function of:

low-speed-drag-polar
f-x-t
thrust-line
landing-gross-weight

Table 53. Subproblem 4-02 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-05

low-speed-drag-polar

Output Parameters To Subproblem 3-05

low-speed-drag-polar

Input Parameters To Subproblem 3-02

f-x-t
thrust-line

Output Parameters To Subproblem 3-02

f-x-t
thrust-line

Input Parameters To Subproblem 3-08

landing-gross-weight

Output Parameters To Subproblem 3-08

landing-gross-weight

Table 53. Subproblem 4-02 Interfaces, cont.

SUCCESSORS

Output Parameters To Subproblem 5-01

landing-descent-gradient

Table 54. Design Relationships in Subproblem 4-03

max-braking-nose-landing-gear-load is a function of:

v-touchdown
braking-effective-thrust
main-landing-gear-location
nose-landing-gear-location
landing-3d-shape

nose-landing-gear-location is an independent design parameter

Table 55. Subproblem 4-03 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-04

braking-effective-thrust

Output Parameters To Subproblem 3-04

braking-effective-thrust

Input Parameters To Subproblem 3-06

main-landing-gear-location

Table 55. Subproblem 4-03 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 5-03

max-braking-nose-landing-gear-load

Input Parameters To Subproblem 5-01

v-touchdown

Output Parameters To Subproblem 5-01

v-touchdown

Input Parameters To Subproblem 5-02

landing-3d-shape

Output Parameters To Subproblem 5-02

landing-3d-shape

Table 56. Design Relationships in Subproblem 4-04

adjusted-take-off-friction-coefficient is a function of:

tire/runway-friction-coefficient
low-speed-drag-polar
take-off-c-l-max

Table 57. Subproblem 4-04 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-01

tire/runway-friction-coefficient

Input Parameters To Subproblem 3-05

low-speed-drag-polar

Output Parameters To Subproblem 3-05

low-speed-drag-polar

Input Parameters To Subproblem 3-03

take-off-c-l-max

Output Parameters To Subproblem 3-03

take-off-c-l-max

Table 58. Design Relationships in Subproblem 4-05

landing-brake-deceleration is a function of:

landing-gross-weight
braking-effective-thrust
v-approach
low-speed-drag-polar

Table 59. Subproblem 4-05 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-08

landing-gross-weight

Output Parameters To Subproblem 3-08

landing-gross-weight

Input Parameters To Subproblem 3-04

braking-effective-thrust

Output Parameters To Subproblem 3-04

braking-effective-thrust

Input Parameters To Subproblem 3-05

low-speed-drag-polar

Output Parameters To Subproblem 3-05

low-speed-drag-polar

SUCCESSORS

Output Parameters To Subproblem 5-01

v-approach
landing-brake-deceleration

Table 60. Design Relationships in Subproblem 4-06

landing-equivalent-inertia-time is a function of:

v-touchdown
landing-gross-weight
f-x-t
thrust-line

Table 61. Subproblem 4-06 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-08

landing-gross-weight

Output Parameters To Subproblem 3-08

landing-gross-weight

Input Parameters To Subproblem 3-02

f-x-t
thrust-line

Output Parameters To Subproblem 3-02

f-x-t
thrust-line

SUCCESSORS

Output Parameters To Subproblem 5-01

landing-equivalent-inertia-time
v-touchdown

Table 62. Design Relationships in Subproblem 4-07

main-landing-gear-attach-point-dynamic-loads is a function of:

main-landing-gear-design-concept
landing-sink-rate
landing-gross-weight

Table 63. Subproblem 4-07 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-08

landing-gross-weight

SUCCESSORS

Input Parameters To Subproblem 5-14

main-landing-gear-attach-point-dynamic-loads
main-landing-gear-design-concept

Output Parameters To Subproblem 5-14

main-landing-gear-attach-point-dynamic-loads
main-landing-gear-design-concept

Input Parameters To Subproblem 5-01

landing-sink-rate

Output Parameters To Subproblem 5-01

landing-sink-rate

Table 64. Design Relationships in Subproblem 4-08

airplane-ac is a function of:

wing-body-ac
horizontal-c-l-alpha
wing-body-c-l-alpha
horizontal-area
wing-planform-area
horizontal-ac
downwash-alpha

static-margin is a function of:

airplane-cg
airplane-ac

trimmed-airplane-alpha is a function of:

cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
phi-t
airplane-ac
horizontal-ac
horizontal-location
trimmed-delta-e
d-t

trimmed-delta-e is a function of:

cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
phi-t
airplane-ac
horizontal-ac
horizontal-location
trimmed-airplane-alpha
d-t

Table 64. Design Relationships in Subproblem 4-08, cont.

trimmed-airplane-beta is a function of:

f-y-t
airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
l-t
n-t
trimmed-airplane-delta-a
trimmed-airplane-delta-r

trimmed-airplane-delta-a is a function of:

f-y-t
airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
l-t
n-t
trimmed-airplane-beta
trimmed-airplane-delta-r

Table 64. Design Relationships in Subproblem 4-08, cont.

trimmed-airplane-delta-r is a function of:

f-y-t
airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
l-t
n-t
trimmed-airplane-delta-a
trimmed-airplane-beta

short-period-natural-frequency is a function of:

trimmed-drag-polar
cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
thrust-line
engine-gross-thrust
installation-losses
airplane-ac
horizontal-ac
horizontal-location
i-y-y

short-period-damping-ratio is a function of:

trimmed-drag-polar
cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
thrust-line
engine-gross-thrust
installation-losses
airplane-ac
horizontal-ac
horizontal-location

Table 64. Design Relationships in Subproblem 4-08, cont.

short-period-damping-ratio is a function of: (cont.)

i-y-y

phugoid-natural-frequency is a function of:

trimmed-drag-polar
cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
thrust-line
engine-gross-thrust
installation-losses
airplane-ac
horizontal-ac
horizontal-location
i-y-y

phugoid-damping-ratio is a function of:

trimmed-drag-polar
cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
thrust-line
engine-gross-thrust
installation-losses
airplane-ac
horizontal-ac
horizontal-location
i-y-y

Table 64. Design Relationships in Subproblem 4-08, cont.

spiral-natural-frequency is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

spiral-damping-ratio is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

roll-natural-frequency is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

Table 64. Design Relationships in Subproblem 4-08, cont.

roll-damping-ratio is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

dutch-roll-natural-frequency is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

dutch-roll-damping-ratio is a function of:

airplane-ac
vertical-ac
vertical-location
vertical-3d-shape
cruise-3d-shape
wing-body-ac
wing-3d-shape
aileron-3d-geometry
rudder-3d-geometry
i-x-x
i-z-z

Table 64. Design Relationships in Subproblem 4-08, cont.

elevator-actuator-rate is a function of:

design-pitch-rate
short-period-natural-frequency
short-period-damping-ratio
phugoid-natural-frequency
phugoid-damping-ratio
cruise-3d-shape
horizontal-3d-shape
elevator-3d-geometry
airplane-ac
horizontal-ac
horizontal-location
i-y-y
flight-design-gross-weight

aileron-actuator-rate is a function of:

design-roll-rate
design-yaw-rate
dutch-roll-natural-frequency
dutch-roll-damping-ratio
cruise-3d-shape
airplane-ac
wing-body-ac
vertical-ac
vertical-location
vertical-3d-shape
wing-3d-shape
aileron-3d-geometry
i-x-x
i-x-z
i-z-z
flight-design-gross-weight

Table 64. Design Relationships in Subproblem 4-08, cont.

rudder-actuator-rate is a function of:

- design-roll-rate
- design-yaw-rate
- dutch-roll-natural-frequency
- dutch-roll-damping-ratio
- cruise-3d-shape
- airplane-ac
- vertical-ac
- vertical-location
- vertical-3d-shape
- rudder-3d-geometry
- i-x-x
- i-x-z
- i-z-z
- flight-design-gross-weight

horizontal-ac is a function of:

- horizontal-3d-shape

cruise-3d-shape is a function of:

- wing-fuselage-3d-shape
- nacelle-3d-shape
- pylon-3d-shape
- vertical-3d-shape
- vertical-location
- horizontal-3d-shape
- horizontal-location

horizontal-3d-shape is a function of:

- horizontal-airfoil-section
- horizontal-area
- horizontal-sweep-angle
- horizontal-taper-ratio
- horizontal-aspect-ratio

elevator-3d-geometry is an independent design parameter

Table 64. Design Relationships in Subproblem 4-08, cont.

phi-t is a function of:

thrust-line

d-t is a function of:

thrust-line

f-y-t is a function of:

thrust-line
engine-net-thrust

l-t is a function of:

thrust-line
engine-net-thrust

n-t is a function of:

thrust-line
engine-net-thrust

take-off-3d-shape is a function of:

cruise-3d-shape
high-lift-device-3d-geometry
take-off-flap-setting

wing-fuselage-3d-shape is a function of:

wing-3d-shape
fuselage-3d-shape

Table 64. Design Relationships in Subproblem 4-08, cont.

engine-net-thrust is a function of:

- engine-gross-thrust
- engine-bleed
- power-extraction
- installation-losses

high-lift-device-3d-geometry is an independent design parameter

pylon-attach-point-loads-cruise is a function of:

- nacelle-pylon-structural-geometry
- nacelle-pylon-structural-weight
- nacelle-pylon-structure-elastic-properties
- nacelle-pylon-structure-moments-of-inertia
- engine-net-thrust
- thrust-line
- engine-mount-locations
- nacelle-pylon-aerodynamic-loads

pylon-attach-point-loads-pull-up is a function of:

- nacelle-pylon-structural-geometry
- nacelle-pylon-structural-weight
- nacelle-pylon-structure-elastic-properties
- nacelle-pylon-structure-moments-of-inertia
- engine-net-thrust
- thrust-line
- engine-mount-locations
- nacelle-pylon-aerodynamic-loads

pylon-attach-point-loads-turn is a function of:

- nacelle-pylon-structural-geometry
- nacelle-pylon-structural-weight
- nacelle-pylon-structure-elastic-properties
- nacelle-pylon-structure-moments-of-inertia
- engine-net-thrust
- thrust-line
- engine-mount-locations
- nacelle-pylon-aerodynamic-loads

Table 64. Design Relationships in Subproblem 4-08, cont.

nacelle-pylon-structural-weight is an independent design parameter

horizontal-airfoil-section is an independent design parameter

horizontal-sweep-angle is an independent design parameter

horizontal-taper-ratio is an independent design parameter

horizontal-aspect-ratio is an independent design parameter

engine-mount-locations is an independent design parameter

engine-gross-thrust is an independent design parameter

engine-bleed is an independent design parameter

nacelle-pylon-structural-geometry is an independent design parameter

nacelle-pylon-structure-elastic-properties is an independent design parameter

nacelle-pylon-structure-moments-of-inertia is an independent design parameter

design-pitch-rate is an independent design parameter

design-roll-rate is an independent design parameter

design-yaw-rate is an independent design parameter

take-off-flap-setting is an independent design parameter

Table 65. Subproblem 4-08 Interfaces

PREDECESSORS

Input Parameters To Subproblem 3-10

wing-body-ac
wing-fuselage-3d-shape

Input Parameters To Subproblem 3-12

airplane-cg
horizontal-area
horizontal-ac

Output Parameters To Subproblem 3-12

airplane-cg
horizontal-area
horizontal-ac

Input Parameters To Subproblem 3-13

trimmed-drag-polar
elevator-3d-geometry
cruise-3d-shape
trimmed-delta-e
trimmed-airplane-alpha

Input Parameters To Subproblem 3-02

thrust-line
engine-net-thrust

Output Parameters To Subproblem 3-02

thrust-line
engine-net-thrust

Input Parameters To Subproblem 3-15

flight-design-gross-weight

Table 65. Subproblem 4-08 Interfaces, cont.

Input Parameters To Subproblem 3-05

high-lift-device-3d-geometry
cruise-3d-shape

Output Parameters To Subproblem 3-05

high-lift-device-3d-geometry
cruise-3d-shape

Input Parameters To Subproblem 3-09

horizontal-3d-shape

Input Parameters To Subproblem 3-03

take-off-3d-shape

Output Parameters To Subproblem 3-03

take-off-3d-shape

Input Parameters To Subproblem 3-11

wing-fuselage-3d-shape

Input Parameters To Subproblem 3-14

engine-net-thrust

Input Parameters To Subproblem 3-16

nacelle-pylon-structural-weight

Output Parameters To Subproblem 3-16

nacelle-pylon-structural-weight

Table 65. Subproblem 4-08 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 5-07

horizontal-c-l-alpha
horizontal-3d-shape

Input Parameters To Subproblem 5-04

wing-body-c-l-alpha
wing-fuselage-3d-shape

Input Parameters To Subproblem 5-14

wing-planform-area
downwash-alpha
aileron-3d-geometry
fuselage-3d-shape
wing-3d-shape
power-extraction
rudder-3d-geometry
vertical-3d-shape
vertical-ac
nacelle-pylon-structural-weight
pylon-attach-point-loads-turn
pylon-attach-point-loads-pull-up
pylon-attach-point-loads-cruise
elevator-3d-geometry
horizontal-3d-shape
cruise-3d-shape
rudder-actuator-rate
aileron-actuator-rate
elevator-actuator-rate

Table 65. Subproblem 4-08 Interfaces, cont.

Output Parameters To Subproblem 5-14

wing-planform-area
downwash-alpha
aileron-3d-geometry
fuselage-3d-shape
wing-3d-shape
power-extraction
rudder-3d-geometry
vertical-3d-shape
vertical-ac
nacelle-pylon-structural-weight
pylon-attach-point-loads-turn
pylon-attach-point-loads-pull-up
pylon-attach-point-loads-cruise
elevator-3d-geometry
horizontal-3d-shape
cruise-3d-shape
rudder-actuator-rate
aileron-actuator-rate
elevator-actuator-rate

Input Parameters To Subproblem 5-06

cruise-3d-shape
static-margin

Input Parameters To Subproblem 5-15

horizontal-location

Input Parameters To Subproblem 5-13

vertical-location

Input Parameters To Subproblem 5-05

installation-losses

Input Parameters To Subproblem 5-17

i-x-x
i-y-y
i-z-z
i-x-z

Table 65. Subproblem 4-08 Interfaces, cont.

Output Parameters To Subproblem 5-17

i-x-x
i-y-y
i-z-z
i-x-z

Input Parameters To Subproblem 5-09

cruise-3d-shape

Input Parameters To Subproblem 5-10

cruise-3d-shape

Input Parameters To Subproblem 5-11

cruise-3d-shape

Input Parameters To Subproblem 5-02

high-lift-device-3d-geometry
cruise-3d-shape

Output Parameters To Subproblem 5-02

high-lift-device-3d-geometry
cruise-3d-shape

Input Parameters To Subproblem 5-08

pylon-3d-shape
nacelle-pylon-aerodynamic-loads
nacelle-3d-shape

Input Parameters To Subproblem 5-18

elevator-3d-geometry
horizontal-3d-shape

Input Parameters To Subproblem 5-12

elevator-3d-geometry

Table 65. Subproblem 4-08 Interfaces, cont.

Input Parameters To Subproblem 5-16

elevator-3d-geometry

Table 66. Design Relationships in Subproblem 4-09

fuselage-cg is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-weight
fuselage-skin-3d-geometry
fuselage-skin-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-weight

Table 67. Subproblem 4-09 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

fuselage-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

fuselage-cg

Output Parameters To Subproblem 5-17

fuselage-cg

Table 67. Subproblem 4-09 Interfaces, cont.

Input Parameters To Subproblem 5-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Output Parameters To Subproblem 5-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Table 68. Design Relationships in Subproblem 4-10

horizontal-cg is a function of:

horizontal-structural-arrangement
horizontal-rib-3d-geometry
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-weight
horizontal-skin-3d-geometry
horizontal-skin-weight

Table 69. Subproblem 4-10 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

horizontal-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

horizontal-cg

Output Parameters To Subproblem 5-17

horizontal-cg

Input Parameters To Subproblem 5-14

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Output Parameters To Subproblem 5-14

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Table 70. Design Relationships in Subproblem 4-11

vertical-cg is a function of:

vertical-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-weight
vertical-stiffener-3d-geometry
vertical-stiffener-weight
vertical-skin-3d-geometry
vertical-skin-weight

Table 71. Subproblem 4-11 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

vertical-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

vertical-cg

Output Parameters To Subproblem 5-17

vertical-cg

Table 71. Subproblem 4-11 Interfaces, cont.

Input Parameters To Subproblem 5-14

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Output Parameters To Subproblem 5-14

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 72. Design Relationships in Subproblem 4-12

wing-cg is a function of:

wing-structural-arrangement
wing-rib-3d-geometry
wing-rib-weight
wing-spar-3d-geometry
wing-spar-weight
wing-stiffener-3d-geometry
wing-stiffener-weight
wing-skin-3d-geometry
wing-skin-weight

Table 73. Subproblem 4-12 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

wing-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

wing-cg

Output Parameters To Subproblem 5-17

wing-cg

Input Parameters To Subproblem 5-14

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Output Parameters To Subproblem 5-14

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

C-2

Table 74. Design Relationships in Subproblem 4-13

main-landing-gear-cg is a function of:

main-landing-gear-3d-geometry

Table 75. Subproblem 4-13 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

main-landing-gear-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

main-landing-gear-cg

Output Parameters To Subproblem 5-17

main-landing-gear-cg

Input Parameters To Subproblem 5-14

main-landing-gear-3d-geometry

Output Parameters To Subproblem 5-14

main-landing-gear-3d-geometry

Table 76. Design Relationships in Subproblem 4-14

nose-landing-gear-cg is a function of:

nose-landing-gear-3d-geometry

Table 77. Subproblem 4-14 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-12

nose-landing-gear-cg

SUCCESSORS

Input Parameters To Subproblem 5-17

nose-landing-gear-cg

Output Parameters To Subproblem 5-17

nose-landing-gear-cg

Input Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry

Output Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry

Table 78. Design Relationships in Subproblem 4-15

fuselage-structural-weight is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-weight
fuselage-skin-3d-geometry
fuselage-skin-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-weight

Table 79. Subproblem 4-15 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

fuselage-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Table 80. Design Relationships in Subproblem 4-16

main-landing-gear-structural-weight is a function of:

main-landing-gear-3d-geometry

Table 81. Subproblem 4-16 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

main-landing-gear-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

main-landing-gear-structural-weight
main-landing-gear-3d-geometry

Table 82. Design Relationships in Subproblem 4-17

wing-structural-weight is a function of:

wing-structural-arrangement
wing-rib-3d-geometry
wing-rib-weight
wing-spar-3d-geometry
wing-spar-weight
wing-stiffener-3d-geometry
wing-stiffener-weight
wing-skin-3d-geometry
wing-skin-weight

Table 83. Subproblem 4-17 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

wing-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Table 84. Design Relationships in Subproblem 4-18

rudder-actuator-weight is a function of:

rudder-actuator-geometry

Table 85. Subproblem 4-18 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-17

rudder-actuator-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

rudder-actuator-geometry

Table 86. Design Relationships in Subproblem 4-19

horizontal-structural-weight is a function of:

horizontal-structural-arrangement
horizontal-rib-3d-geometry
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-weight
horizontal-skin-3d-geometry
horizontal-skin-weight

Table 87. Subproblem 4-19 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

horizontal-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Table 88. Design Relationships in Subproblem 4-20

aileron-actuator-weight is a function of:

aileron-actuator-geometry

Table 89. Subproblem 4-20 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-17

aileron-actuator-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

aileron-actuator-geometry

Table 90. Design Relationships in Subproblem 4-21

elevator-actuator-weight is a function of:

elevator-actuator-geometry

Table 91. Subproblem 4-21 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-17

elevator-actuator-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

elevator-actuator-geometry

Table 92. Design Relationships in Subproblem 4-22

vertical-structural-weight is a function of:

vertical-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-weight
vertical-stiffener-3d-geometry
vertical-stiffener-weight
vertical-skin-3d-geometry
vertical-skin-weight

Table 93. Subproblem 4-22 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

vertical-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-14

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 94. Design Relationships in Subproblem 4-23

nose-landing-gear-structural-weight is a function of:

nose-landing-gear-3d-geometry

Table 95. Subproblem 4-23 Interfaces

PREDECESSORS

Output Parameters To Subproblem 3-16

nose-landing-gear-structural-weight

SUCCESSORS

Output Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry

Table 96. Design Relationships in Subproblem 5-01

v-approach is a function of:

v-stall-landing

landing-sink-rate is a function of:

v-approach
landing-descent-gradient

Table 96. Design Relationships in Subproblem 5-01, cont.

v-touchdown is a function of:

v-approach
landing-descent-gradient
flare-load-factor

landing-distance-from-screen-to-touchdown is a function of:

v-approach
v-touchdown
landing-descent-gradient

landing-distance-from-touchdown is a function of:

v-touchdown
landing-brake-deceleration
landing-equivalent-inertia-time

flare-load-factor is an independent design parameter

Table 97. Subproblem 5-01 Interfaces

PREDECESSORS

Input Parameters To Subproblem 4-05

v-approach
landing-brake-deceleration

Input Parameters To Subproblem 4-01

v-stall-landing

Output Parameters To Subproblem 4-01

v-stall-landing

Table 97. Subproblem 5-01 Interfaces, cont.

Input Parameters To Subproblem 4-07

landing-sink-rate

Output Parameters To Subproblem 4-07

landing-sink-rate

Input Parameters To Subproblem 4-02

landing-descent-gradient

Input Parameters To Subproblem 4-06

landing-equivalent-inertia-time
v-touchdown

Input Parameters To Subproblem 4-03

v-touchdown

Output Parameters To Subproblem 4-03

v-touchdown

SUCCESSORS

Input Parameters To Subproblem 6-01

landing-distance-from-touchdown
landing-distance-from-screen-to-touchdown

Table 98. Design Relationships in Subproblem 5-02

landing-3d-shape is a function of:

cruise-3d-shape
high-lift-device-3d-geometry
landing-flap-setting

landing-c-l-max is a function of:

landing-3d-shape

landing-flap-setting is an independent design parameter

Table 99. Subproblem 5-02 Interfaces

PREDECESSORS

Input Parameters To Subproblem 4-03

landing-3d-shape

Output Parameters To Subproblem 4-03

landing-3d-shape

Input Parameters To Subproblem 4-08

high-lift-device-3d-geometry
cruise-3d-shape

Output Parameters To Subproblem 4-08

high-lift-device-3d-geometry
cruise-3d-shape

Input Parameters To Subproblem 4-01

landing-c-l-max

Table 99. Subproblem 5-02 Interfaces, cont.

Output Parameters To Subproblem 4-01

landing-c-l-max

Table 100. Design Relationships in Subproblem 5-03

nose-landing-gear-attach-point-loads is a function of:

max-braking-nose-landing-gear-load
nose-landing-gear-design-concept

Table 101. Subproblem 5-03 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-03

max-braking-nose-landing-gear-load

SUCCESSORS

Output Parameters To Subproblem 6-10

nose-landing-gear-design-concept

Table 102. Design Relationships in Subproblem 5-04

wing-body-c-l-alpha is a function of:

wing-fuselage-3d-shape

Table 103. Subproblem 5-04 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

wing-body-c-l-alpha
wing-fuselage-3d-shape

Table 104. Design Relationships in Subproblem 5-05

installation-losses is a function of:

inlet-pressure-recovery
inlet-distortion
ram-drag
boattail-drag

Table 105. Subproblem 5-05 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

installation-losses

Table 105. Subproblem 5-05 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 6-02

inlet-pressure-recovery

Input Parameters To Subproblem 6-03

inlet-distortion

Input Parameters To Subproblem 6-04

ram-drag

Output Parameters To Subproblem 6-04

ram-drag

Input Parameters To Subproblem 6-05

boattail-drag

Table 106. Design Relationships in Subproblem 5-06

airplane-c-l-alpha is a function of:

cruise-3d-shape

airplane-c-m-alpha is a function of:

airplane-c-l-alpha
static-margin

Table 107. Subproblem 5-06 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

cruise-3d-shape
static-margin

Table 108. Design Relationships in Subproblem 5-07

horizontal-c-l-alpha is a function of:

horizontal-3d-shape

Table 109. Subproblem 5-07 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

horizontal-c-l-alpha
horizontal-3d-shape

Table 110. Design Relationships in Subproblem 5-08

nacelle-3d-shape is an independent design parameter

nacelle-pylon-aerodynamic-loads is a function of:

nacelle-3d-shape
pylon-3d-shape

Table 110. Design Relationships in Subproblem 5-08, cont.

pylon-3d-shape is an independent design parameter

Table 111. Subproblem 5-08 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

pylon-3d-shape
nacelle-pylon-aerodynamic-loads
nacelle-3d-shape

SUCCESSORS

Output Parameters To Subproblem 6-04

nacelle-3d-shape

Table 112. Design Relationships in Subproblem 5-09

fuselage-aerodynamic-loads-cruise is a function of:

cruise-3d-shape

Table 113. Subproblem 5-09 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

cruise-3d-shape

SUCCESSORS

Output Parameters To Subproblem 6-06

fuselage-aerodynamic-loads-cruise

Table 114. Design Relationships in Subproblem 5-10

horizontal-aerodynamic-loads-cruise is a function of:

cruise-3d-shape

Table 115. Subproblem 5-10 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

cruise-3d-shape

SUCCESSORS

Output Parameters To Subproblem 6-06

horizontal-aerodynamic-loads-cruise

Table 116. Design Relationships in Subproblem 5-11

vertical-aerodynamic-loads-cruise is a function of:

cruise-3d-shape

Table 117. Subproblem 5-11 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

cruise-3d-shape

SUCCESSORS

Output Parameters To Subproblem 6-06

vertical-aerodynamic-loads-cruise

Table 118. Design Relationships in Subproblem 5-12

alpha-pull-up is a function of:

load-factor
elevator-3d-geometry
maneuvering-3d-shape-pull-up

Table 119. Subproblem 5-12 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

elevator-3d-geometry

SUCCESSORS

Input Parameters To Subproblem 6-18

load-factor

Output Parameters To Subproblem 6-18

load-factor

Input Parameters To Subproblem 6-06

maneuvering-3d-shape-pull-up

Output Parameters To Subproblem 6-06

maneuvering-3d-shape-pull-up

Table 120. Design Relationships in Subproblem 5-13

vertical-location is an independent design parameter

Table 121. Subproblem 5-13 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

vertical-location

SUCCESSORS

Output Parameters To Subproblem 6-06

vertical-location

Table 122. Design Relationships in Subproblem 5-14

vertical-ac is a function of:

vertical-3d-shape

vertical-3d-shape is a function of:

vertical-airfoil-section
vertical-area
vertical-sweep-angle
vertical-taper-ratio
vertical-aspect-ratio

vertical-skin-3d-geometry is a function of:

vertical-3d-shape

Table 122. Design Relationships in Subproblem 5-14, cont.

rudder-actuator-geometry is a function of:

hydraulic-system-pressure
rudder-max-hinge-moment
vertical-structural-arrangement
rudder-3d-geometry
vertical-3d-shape

vertical-skin-weight is a function of:

vertical-skin-3d-geometry

aircraft-normal-mode-shapes-flight is a function of:

vertical-structural-arrangement
horizontal-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-rib-weight
vertical-spar-weight
vertical-stiffener-weight
vertical-skin-weight
vertical-rib-moments-of-inertia
vertical-spar-moments-of-inertia
vertical-stiffener-moments-of-inertia
vertical-skin-moments-of-inertia
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-shapes-flight is a function of: (cont.)

horizontal-rib-weight
horizontal-spar-weight
horizontal-stiffener-weight
horizontal-skin-weight
horizontal-rib-moments-of-inertia
horizontal-spar-moments-of-inertia
horizontal-stiffener-moments-of-inertia
horizontal-skin-moments-of-inertia
wing-structural-arrangement
nacelle-pylon-structural-weight
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-rib-weight
wing-spar-weight
wing-stiffener-weight
wing-skin-weight
wing-rib-moments-of-inertia
wing-spar-moments-of-inertia
wing-stiffener-moments-of-inertia
wing-skin-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-shapes-flight is a function of: (cont.)

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-flight is a function of:

vertical-structural-arrangement
horizontal-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-rib-weight
vertical-spar-weight
vertical-stiffener-weight
vertical-skin-weight.
vertical-rib-moments-of-inertia
vertical-spar-moments-of-inertia
vertical-stiffener-moments-of-inertia
vertical-skin-moments-of-inertia
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-flight is a function of: (cont.)

horizontal-rib-weight
horizontal-spar-weight
horizontal-stiffener-weight
horizontal-skin-weight
horizontal-rib-moments-of-inertia
horizontal-spar-moments-of-inertia
horizontal-stiffener-moments-of-inertia
horizontal-skin-moments-of-inertia
wing-structural-arrangement
nacelle-pylon-structural-weight
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-rib-weight
wing-spar-weight
wing-stiffener-weight
wing-skin-weight
wing-rib-moments-of-inertia
wing-spar-moments-of-inertia
wing-stiffener-moments-of-inertia
wing-skin-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-flight is a function of: (cont.)

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-shapes-landing is a function of:

vertical-structural-arrangement
horizontal-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-rib-weight
vertical-spar-weight
vertical-stiffener-weight
vertical-skin-weight
vertical-rib-moments-of-inertia
vertical-spar-moments-of-inertia
vertical-stiffener-moments-of-inertia
vertical-skin-moments-of-inertia
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-shapes-landing is a function of: (cont.)

horizontal-rib-weight
horizontal-spar-weight
horizontal-stiffener-weight
horizontal-skin-weight
horizontal-rib-moments-of-inertia
horizontal-spar-moments-of-inertia
horizontal-stiffener-moments-of-inertia
horizontal-skin-moments-of-inertia
wing-structural-arrangement
nacelle-pylon-structural-weight
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-rib-weight
wing-spar-weight
wing-stiffener-weight
wing-skin-weight
wing-rib-moments-of-inertia
wing-spar-moments-of-inertia
wing-stiffener-moments-of-inertia
wing-skin-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-shapes-landing is a function of: (cont.)

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry
main-landing-gear-structural-weight
main-landing-gear-design-concept

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-landing is a function of:

vertical-structural-arrangement
horizontal-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-rib-weight
vertical-spar-weight
vertical-stiffener-weight
vertical-skin-weight
vertical-rib-moments-of-inertia
vertical-spar-moments-of-inertia
vertical-stiffener-moments-of-inertia
vertical-skin-moments-of-inertia
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-landing is a function of: (cont.)

horizontal-rib-weight
horizontal-spar-weight
horizontal-stiffener-weight
horizontal-skin-weight
horizontal-rib-moments-of-inertia
horizontal-spar-moments-of-inertia
horizontal-stiffener-moments-of-inertia
horizontal-skin-moments-of-inertia
wing-structural-arrangement
nacelle-pylon-structural-weight
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-rib-weight
wing-spar-weight
wing-stiffener-weight
wing-skin-weight
wing-rib-moments-of-inertia
wing-spar-moments-of-inertia
wing-stiffener-moments-of-inertia
wing-skin-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

aircraft-normal-mode-frequencies-landing is a function of: (cont.)

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry
main-landing-gear-structural-weight
main-landing-gear-design-concept

control-system-power-requirement is a function of:

elevator-actuator-geometry
aileron-actuator-geometry
rudder-actuator-geometry
elevator-actuator-rate
aileron-actuator-rate
rudder-actuator-rate
hydraulic-system-pressure

vertical-structural-arrangement is an independent design parameter

rudder-3d-geometry is an independent design parameter

horizontal-structural-arrangement is an independent design parameter

vertical-rib-3d-geometry is an independent design parameter

Table 122. Design Relationships in Subproblem 5-14, cont.

vertical-spar-3d-geometry is an independent design parameter

vertical-stiffener-3d-geometry is an independent design parameter

vertical-rib-weight is a function of:

vertical-rib-3d-geometry

vertical-spar-weight is a function of:

vertical-spar-3d-geometry

vertical-stiffener-weight is a function of:

vertical-stiffener-3d-geometry

horizontal-rib-3d-geometry is an independent design parameter

horizontal-spar-3d-geometry is an independent design parameter

horizontal-stiffener-3d-geometry is an independent design parameter

horizontal-skin-3d-geometry is a function of:

horizontal-3d-shape

horizontal-rib-weight is a function of:

horizontal-rib-3d-geometry

horizontal-spar-weight is a function of:

horizontal-spar-3d-geometry

Table 122. Design Relationships in Subproblem 5-14, cont.

horizontal-stiffener-weight is a function of:

horizontal-stiffener-3d-geometry

horizontal-skin-weight is a function of:

horizontal-skin-3d-geometry

wing-structural-arrangement is an independent design parameter

wing-rib-3d-geometry is an independent design parameter

wing-spar-3d-geometry is an independent design parameter

wing-stiffener-3d-geometry is an independent design parameter

wing-skin-3d-geometry is a function of:

wing-3d-shape

wing-rib-weight is a function of:

wing-rib-3d-geometry

wing-spar-weight is a function of:

wing-spar-3d-geometry

wing-stiffener-weight is a function of:

wing-stiffener-3d-geometry

wing-skin-weight is a function of:

wing-skin-3d-geometry

Table 122. Design Relationships in Subproblem 5-14, cont.

fuselage-structural-arrangement is an independent design parameter

fuselage-frame-3d-geometry is an independent design parameter

fuselage-frame-weight is a function of:

fuselage-frame-3d-geometry

fuselage-stiffener-3d-geometry is an independent design parameter

fuselage-stiffener-weight is a function of:

fuselage-stiffener-3d-geometry

fuselage-skin-3d-geometry is a function of:

fuselage-3d-shape

fuselage-skin-weight is a function of:

fuselage-skin-3d-geometry

wing-skin-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

wing-spar-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-rib-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

wing-stiffener-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

fuselage-skin-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

fuselage-frame-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

fuselage-stiffener-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

horizontal-skin-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

Table 122. Design Relationships in Subproblem 5-14, cont.

horizontal-spar-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

horizontal-rib-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

horizontal-stiffener-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

vertical-skin-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

vertical-spar-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

vertical-rib-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

Table 122. Design Relationships in Subproblem 5-14, cont.

vertical-stiffener-deformations-landing is a function of:

main-landing-gear-attach-point-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-shapes-landing
aircraft-normal-mode-frequencies-landing

main-landing-gear-3d-geometry is a function of:

main-landing-gear-design-concept

main-landing-gear-design-concept is an independent design parameter

power-extraction is a function of:

control-system-power-requirement

elevator-actuator-geometry is a function of:

hydraulic-system-pressure
elevator-max-hinge-moment
horizontal-structural-arrangement
elevator-3d-geometry
horizontal-3d-shape

aileron-actuator-geometry is a function of:

hydraulic-system-pressure
aileron-max-hinge-moment
wing-structural-arrangement
aileron-3d-geometry
wing-3d-shape

rudder-quasi-steady-aerodynamic-loads is a function of:

rudder-3d-geometry
horizontal-3d-shape
rudder-actuator-normal-mode-shapes

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-attach-point-loads-cruise is a function of:

wing-aerodynamic-loads-cruise
wing-structural-arrangement
pylon-attach-point-loads-cruise
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-weight
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-weight
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-rib-deformations-cruise is a function of:

wing-aerodynamic-loads-cruise
wing-structural-arrangement
pylon-attach-point-loads-cruise
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-weight
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-weight
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-weight
wing-skin-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-rib-deformations-cruise is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-stiffener-deformations-cruise is a function of:

wing-aerodynamic-loads-cruise
wing-structural-arrangement
pylon-attach-point-loads-cruise
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-weight
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-weight
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia.

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-spar-deformations-cruise is a function of:

wing-aerodynamic-loads-cruise
wing-structural-arrangement
pylon-attach-point-loads-cruise
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-weight
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-weight
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-skin-deformations-cruise is a function of:

wing-aerodynamic-loads-cruise
wing-structural-arrangement
pylon-attach-point-loads-cruise
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-weight
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-weight
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-skin-deformations-cruise is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-attach-point-loads-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-rib-deformations-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-stiffener-deformations-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-stiffener-deformations-pull-up is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-spar-deformations-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-skin-deformations-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-maneuvering-shape-pull-up is a function of:

wing-aerodynamic-loads-pull-up
wing-structural-arrangement
pylon-attach-point-loads-pull-up
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-maneuvering-shape-pull-up is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-attach-point-loads-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-rib-deformations-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-stiffener-deformations-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-stiffener-deformations-turn is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-spar-deformations-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-skin-deformations-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-maneuvering-shape-turn is a function of:

wing-aerodynamic-loads-turn
wing-structural-arrangement
pylon-attach-point-loads-turn
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-rib-weight
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-spar-weight
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-skin-weight

Table 122. Design Relationships in Subproblem 5-14, cont.

wing-maneuvering-shape-turn is a function of: (cont.)

wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-weight
wing-stiffener-moments-of-inertia

wing-3d-shape is a function of:

wing-airfoil-section
wing-dihedral
wing-aspect-ratio
wing-sweep-angle
wing-taper-ratio
wing-planform-area

fuselage-3d-shape is an independent design parameter

elevator-max-hinge-moment is a function of:

max-horizontal-alpha
max-elevator-delta-e
elevator-3d-geometry

aileron-3d-geometry is an independent design parameter

wing-aerodynamic-loads-cruise is a function of:

cruise-3d-shape

downwash-alpha is a function of:

wing-3d-shape

wing-planform-area is an independent design parameter

Table 122. Design Relationships in Subproblem 5-14, cont.

aileron-quasi-steady-aerodynamic-loads is a function of:

aileron-3d-geometry
horizontal-3d-shape
aileron-actuator-normal-mode-shapes

vertical-airfoil-section is an independent design parameter

vertical-area is an independent design parameter

vertical-sweep-angle is an independent design parameter

vertical-taper-ratio is an independent design parameter

vertical-aspect-ratio is an independent design parameter

wing-airfoil-section is an independent design parameter

wing-dihedral is an independent design parameter

wing-aspect-ratio is an independent design parameter

wing-sweep-angle is an independent design parameter

wing-taper-ratio is an independent design parameter

max-horizontal-alpha is an independent design parameter

max-elevator-delta-e is an independent design parameter

hydraulic-system-pressure is an independent design parameter

Table 123. Subproblem 5-14 Interfaces

PREDECESSORS

Input Parameters To Subproblem 4-08

wing-planform-area
downwash-alpha
aileron-3d-geometry
fuselage-3d-shape
wing-3d-shape
power-extraction
rudder-3d-geometry
vertical-3d-shape
vertical-ac
nacelle-pylon-structural-weight
pylon-attach-point-loads-turn
pylon-attach-point-loads-pull-up
pylon-attach-point-loads-cruise
elevator-3d-geometry
horizontal-3d-shape
cruise-3d-shape
rudder-actuator-rate
aileron-actuator-rate
elevator-actuator-rate

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 4-08

wing-planform-area
downwash-alpha
aileron-3d-geometry
fuselage-3d-shape
wing-3d-shape
power-extraction
rudder-3d-geometry
vertical-3d-shape
vertical-ac
nacelle-pylon-structural-weight
pylon-attach-point-loads-turn
pylon-attach-point-loads-pull-up
pylon-attach-point-loads-cruise
elevator-3d-geometry
horizontal-3d-shape
cruise-3d-shape
rudder-actuator-rate
aileron-actuator-rate
elevator-actuator-rate

Input Parameters To Subproblem 4-22

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Input Parameters To Subproblem 4-11

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 4-11

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Input Parameters To Subproblem 4-18

rudder-actuator-geometry

Input Parameters To Subproblem 4-16

main-landing-gear-structural-weight
main-landing-gear-3d-geometry

Input Parameters To Subproblem 4-19

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Input Parameters To Subproblem 4-10

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 4-10

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Input Parameters To Subproblem 4-17

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Input Parameters To Subproblem 4-12

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 4-12

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Input Parameters To Subproblem 4-15

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Input Parameters To Subproblem 4-09

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Output Parameters To Subproblem 4-09

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Input Parameters To Subproblem 4-07

main-landing-gear-attach-point-dynamic-loads
main-landing-gear-design-concept

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 4-07

main-landing-gear-attach-point-dynamic-loads
main-landing-gear-design-concept

Input Parameters To Subproblem 4-13

main-landing-gear-3d-geometry

Output Parameters To Subproblem 4-13

main-landing-gear-3d-geometry

Input Parameters To Subproblem 4-21

elevator-actuator-geometry

Input Parameters To Subproblem 4-20

aileron-actuator-geometry

Table 123. Subproblem 5-14 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 6-06

wing-aerodynamic-loads-turn
horizontal-stiffener-moments-of-inertia
horizontal-stiffener-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-elastic-properties
vertical-stiffener-moments-of-inertia
vertical-stiffener-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-elastic-properties
wing-aerodynamic-loads-pull-up

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-06 (cont.)

aileron-3d-geometry
wing-maneuvering-shape-turn
wing-attach-point-loads-turn
wing-maneuvering-shape-pull-up
wing-attach-point-loads-pull-up
wing-attach-point-loads-cruise
vertical-stiffener-deformations-landing
vertical-rib-deformations-landing
vertical-spar-deformations-landing
vertical-skin-deformations-landing
horizontal-stiffener-deformations-landing
horizontal-rib-deformations-landing
horizontal-spar-deformations-landing
horizontal-skin-deformations-landing
fuselage-stiffener-deformations-landing
fuselage-frame-deformations-landing
fuselage-skin-deformations-landing
fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement
horizontal-skin-weight
horizontal-stiffener-weight

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-06 (cont.)

horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
horizontal-structural-arrangement
rudder-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 6-06

wing-aerodynamic-loads-turn
horizontal-stiffener-moments-of-inertia
horizontal-stiffener-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-elastic-properties
vertical-stiffener-moments-of-inertia
vertical-stiffener-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-elastic-properties
wing-aerodynamic-loads-pull-up
aileron-3d-geometry
wing-maneuvering-shape-turn

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 6-06 (cont.)

wing-attach-point-loads-turn
wing-maneuvering-shape-pull-up
wing-attach-point-loads-pull-up
wing-attach-point-loads-cruise
vertical-stiffener-deformations-landing
vertical-rib-deformations-landing
vertical-spar-deformations-landing
vertical-skin-deformations-landing
horizontal-stiffener-deformations-landing
horizontal-rib-deformations-landing
horizontal-spar-deformations-landing
horizontal-skin-deformations-landing
fuselage-stiffener-deformations-landing
fuselage-frame-deformations-landing
fuselage-skin-deformations-landing
fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement
horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight

Table 123. Subproblem 5-14 Interfaces, cont.

Output Parameters To Subproblem 6-06 (cont.)

horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
horizontal-structural-arrangement
rudder-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Input Parameters To Subproblem 6-12

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Output Parameters To Subproblem 6-12

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-07

rudder-actuator-normal-mode-shapes
rudder-quasi-steady-aerodynamic-loads
rudder-actuator-geometry

Input Parameters To Subproblem 6-08

rudder-max-hinge-moment
rudder-3d-geometry

Input Parameters To Subproblem 6-09

aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-frequencies-flight
aircraft-normal-mode-shapes-flight

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-11

wing-stiffener-moments-of-inertia
wing-stiffener-elastic-properties
wing-skin-moments-of-inertia
wing-skin-elastic-properties
wing-spar-moments-of-inertia
wing-spar-elastic-properties
wing-rib-moments-of-inertia
wing-rib-elastic-properties
wing-skin-deformations-turn
wing-spar-deformations-turn
wing-stiffener-deformations-turn
wing-rib-deformations-turn
wing-skin-deformations-pull-up
wing-spar-deformations-pull-up
wing-stiffener-deformations-pull-up
wing-rib-deformations-pull-up
wing-skin-deformations-cruise
wing-spar-deformations-cruise
wing-stiffener-deformations-cruise
wing-rib-deformations-cruise
wing-stiffener-deformations-landing
wing-rib-deformations-landing
wing-spar-deformations-landing
wing-skin-deformations-landing
wing-skin-3d-geometry
wing-stiffener-3d-geometry

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-11 (cont.)

wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Input Parameters To Subproblem 6-23

aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-frequencies-landing
aircraft-normal-mode-shapes-landing

Input Parameters To Subproblem 6-13

main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry

Output Parameters To Subproblem 6-13

main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry

Input Parameters To Subproblem 6-16

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Output Parameters To Subproblem 6-16

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-15

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Output Parameters To Subproblem 6-15

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Input Parameters To Subproblem 6-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Output Parameters To Subproblem 6-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Table 123. Subproblem 5-14 Interfaces, cont.

Input Parameters To Subproblem 6-19

main-landing-gear-design-concept
main-landing-gear-3d-geometry

Input Parameters To Subproblem 6-20

elevator-actuator-geometry

Output Parameters To Subproblem 6-20

elevator-actuator-geometry

Input Parameters To Subproblem 6-21

aileron-actuator-normal-mode-shapes
aileron-quasi-steady-aerodynamic-loads
aileron-actuator-geometry

Input Parameters To Subproblem 6-22

aileron-max-hinge-moment
aileron-3d-geometry

Input Parameters To Subproblem 6-24

wing-3d-shape

Table 124. Design Relationships in Subproblem 5-15

horizontal-location is an independent design parameter

Table 125. Subproblem 5-15 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

horizontal-location

SUCCESSORS

Output Parameters To Subproblem 6-06

horizontal-location

Table 126. Design Relationships in Subproblem 5-16

delta-e-pull-up is a function of:

maneuvering-3d-shape-pull-up
load-factor
elevator-3d-geometry

Table 127. Subproblem 5-16 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

elevator-3d-geometry

Table 127. Subproblem 5-16 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 6-06

maneuvering-3d-shape-pull-up

Output Parameters To Subproblem 6-06

maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 6-18

load-factor

Output Parameters To Subproblem 6-18

load-factor

Table 128. Design Relationships in Subproblem 5-17

i-x-x is a function of:

fuselage-moments-of-inertia
fuselage-cg
wing-moments-of-inertia
wing-cg
vertical-moments-of-inertia
vertical-cg
horizontal-moments-of-inertia
horizontal-cg
main-landing-gear-moments-of-inertia
main-landing-gear-cg
nose-landing-gear-moments-of-inertia
nose-landing-gear-cg

Table 128. Design Relationships in Subproblem 5-17, cont.

i-y-y is a function of:

fuselage-moments-of-inertia
fuselage-cg
wing-moments-of-inertia
wing-cg
vertical-moments-of-inertia
vertical-cg
horizontal-moments-of-inertia
horizontal-cg
main-landing-gear-moments-of-inertia
main-landing-gear-cg
nose-landing-gear-moments-of-inertia
nose-landing-gear-cg

i-z-z is a function of:

fuselage-moments-of-inertia
fuselage-cg
wing-moments-of-inertia
wing-cg
vertical-moments-of-inertia
vertical-cg
horizontal-moments-of-inertia
horizontal-cg
main-landing-gear-moments-of-inertia
main-landing-gear-cg
nose-landing-gear-moments-of-inertia
nose-landing-gear-cg

i-z-y is a function of:

fuselage-moments-of-inertia
fuselage-cg
wing-moments-of-inertia
wing-cg
vertical-moments-of-inertia
vertical-cg
horizontal-moments-of-inertia
horizontal-cg
main-landing-gear-moments-of-inertia
main-landing-gear-cg

Table 128. Design Relationships in Subproblem 5-17, cont.

i-z-y is a function of: (cont.)

nose-landing-gear-moments-of-inertia
nose-landing-gear-cg

i-x-z is a function of:

fuselage-moments-of-inertia
fuselage-cg
wing-moments-of-inertia
wing-cg
vertical-moments-of-inertia
vertical-cg
horizontal-moments-of-inertia
horizontal-cg
main-landing-gear-moments-of-inertia
main-landing-gear-cg
nose-landing-gear-moments-of-inertia
nose-landing-gear-cg

Table 129. Subproblem 5-17 Interfaces

PREDECESSORS

Input Parameters To Subproblem 4-08

i-x-z
i-z-z
i-y-y
i-x-x

Output Parameters To Subproblem 4-08

i-x-z
i-z-z
i-y-y
i-x-x

Table 129. Subproblem 5-17 Interfaces, cont.

Input Parameters To Subproblem 4-09

fuselage-cg

Output Parameters To Subproblem 4-09

fuselage-cg

Input Parameters To Subproblem 4-12

wing-cg

Output Parameters To Subproblem 4-12

wing-cg

Input Parameters To Subproblem 4-11

vertical-cg

Output Parameters To Subproblem 4-11

vertical-cg

Input Parameters To Subproblem 4-10

horizontal-cg

Output Parameters To Subproblem 4-10

horizontal-cg

Input Parameters To Subproblem 4-13

main-landing-gear-cg

Output Parameters To Subproblem 4-13

main-landing-gear-cg

Input Parameters To Subproblem 4-14

nose-landing-gear-cg

Table 129. Subproblem 5-17 Interfaces, cont.

Output Parameters To Subproblem 4-14

nose-landing-gear-cg

SUCCESSORS

Input Parameters To Subproblem 6-14

fuselage-moments-of-inertia

Output Parameters To Subproblem 6-14

fuselage-moments-of-inertia

Input Parameters To Subproblem 6-15

wing-moments-of-inertia

Output Parameters To Subproblem 6-15

wing-moments-of-inertia

Input Parameters To Subproblem 6-12

vertical-moments-of-inertia

Output Parameters To Subproblem 6-12

vertical-moments-of-inertia

Input Parameters To Subproblem 6-16

horizontal-moments-of-inertia

Output Parameters To Subproblem 6-16

horizontal-moments-of-inertia

Input Parameters To Subproblem 6-13

main-landing-gear-moments-of-inertia

Table 129. Subproblem 5-17 Interfaces, cont.

Output Parameters To Subproblem 6-13

main-landing-gear-moments-of-inertia

Input Parameters To Subproblem 6-17

nose-landing-gear-moments-of-inertia

Output Parameters To Subproblem 6-17

nose-landing-gear-moments-of-inertia

Input Parameters To Subproblem 6-06

i-x-z
i-z-y
i-z-z

Output Parameters To Subproblem 6-06

i-x-z
i-z-y
i-z-z

Table 130. Design Relationships in Subproblem 5-18

elevator-quasi-steady-aerodynamic-loads is a function of:

elevator-3d-geometry
horizontal-3d-shape
elevator-actuator-normal-mode-shapes

Table 131. Subproblem 5-18 Interfaces

PREDECESSORS

Output Parameters To Subproblem 4-08

elevator-3d-geometry
horizontal-3d-shape

SUCCESSORS

Output Parameters To Subproblem 6-20

elevator-quasi-steady-aerodynamic-loads
elevator-actuator-normal-mode-shapes

Table 132. Design Relationships in Subproblem 5-19

nose-landing-gear-3d-geometry is a function of:

nose-landing-gear-design-concept

Table 133. Subproblem 5-19 Interfaces

PREDECESSORS

Input Parameters To Subproblem 4-23

nose-landing-gear-3d-geometry

Input Parameters To Subproblem 4-14

nose-landing-gear-3d-geometry

Output Parameters To Subproblem 4-14

nose-landing-gear-3d-geometry

Table 133. Subproblem 5-19 Interfaces, cont.

SUCCESSORS

Input Parameters To Subproblem 6-17

nose-landing-gear-3d-geometry

Output Parameters To Subproblem 6-17

nose-landing-gear-3d-geometry

Input Parameters To Subproblem 6-10

nose-landing-gear-3d-geometry
nose-landing-gear-design-concept

Output Parameters To Subproblem 6-10

nose-landing-gear-3d-geometry
nose-landing-gear-design-concept

Table 134. Design Relationships in Subproblem 6-01

landing-distance is a function of:

landing-distance-from-screen-to-touchdown
landing-distance-from-touchdown

Table 135. Subproblem 6-01 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-01

landing-distance-from-touchdown
landing-distance-from-screen-to-touchdown

Table 136. Design Relationships in Subproblem 6-02

inlet-pressure-recovery is a function of:

inlet-3d-geometry

Table 137. Subproblem 6-02 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-05

inlet-pressure-recovery

SUCCESSORS

Output Parameters To Subproblem 7-01

inlet-3d-geometry

Table 138. Design Relationships in Subproblem 6-03

inlet-distortion is a function of:

inlet-3d-geometry

Table 139. Subproblem 6-03 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-05

inlet-distortion

SUCCESSORS

Output Parameters To Subproblem 7-01

inlet-3d-geometry

Table 140. Design Relationships in Subproblem 6-04

ram-drag is a function of:

engine-massflow
inlet-3d-geometry
nacelle-3d-shape

engine-massflow is an independent design parameter

Table 141. Subproblem 6-04 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-05

ram-drag

Output Parameters To Subproblem 5-05

ram-drag

Table 141. Subproblem 6-04 Interfaces, cont.

Input Parameters To Subproblem 5-08

nacelle-3d-shape

SUCCESSORS

Input Parameters To Subproblem 7-01

inlet-3d-geometry

Output Parameters To Subproblem 7-01

inlet-3d-geometry

Table 142. Design Relationships in Subproblem 6-05

boattail-drag is a function of:

nozzle-3d-geometry

nozzle-3d-geometry is an independent design parameter

Table 143. Subproblem 6-05 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-05

boattail-drag

Table 144. Design Relationships in Subproblem 6-06

maneuvering-3d-shape-pull-up is a function of:

wing-maneuvering-shape-pull-up
fuselage-maneuvering-shape-pull-up
vertical-maneuvering-shape-pull-up
vertical-location
horizontal-location
horizontal-maneuvering-shape-pull-up

wing-aerodynamic-loads-pull-up is a function of:

maneuvering-3d-shape-pull-up

fuselage-maneuvering-shape-pull-up is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-pull-up
wing-attach-point-loads-pull-up
empennage-attach-point-loads-pull-up

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-maneuvering-shape-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

horizontal-maneuvering-shape-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-maneuvering-shape-pull-up is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

fuselage-frame-elastic-properties is an independent design parameter

fuselage-frame-moments-of-inertia is an independent design parameter

fuselage-stiffener-elastic-properties is an independent design parameter

fuselage-stiffener-moments-of-inertia is an independent design parameter

fuselage-skin-elastic-properties is an independent design parameter

fuselage-skin-moments-of-inertia is an independent design parameter

Table 144. Design Relationships in Subproblem 6-06, cont.

empennage-attach-point-loads-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

horizontal-attach-point-loads-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-attach-point-loads-pull-up is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

vertical-rib-elastic-properties is an independent design parameter

vertical-rib-moments-of-inertia is an independent design parameter

vertical-spar-elastic-properties is an independent design parameter

vertical-spar-moments-of-inertia is an independent design parameter

vertical-skin-elastic-properties is an independent design parameter

vertical-skin-moments-of-inertia is an independent design parameter

vertical-stiffener-elastic-properties is an independent design parameter

vertical-stiffener-moments-of-inertia is an independent design parameter

horizontal-rib-elastic-properties is an independent design parameter

horizontal-rib-moments-of-inertia is an independent design parameter

horizontal-spar-elastic-properties is an independent design parameter

horizontal-spar-moments-of-inertia is an independent design parameter

horizontal-skin-elastic-properties is an independent design parameter

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-skin-moments-of-inertia is an independent design parameter

horizontal-stiffener-elastic-properties is an independent design parameter

horizontal-stiffener-moments-of-inertia is an independent design parameter

fuselage-frame-deformations-cruise is a function of:

- fuselage-structural-arrangement
- fuselage-frame-3d-geometry
- fuselage-frame-elastic-properties
- fuselage-frame-moments-of-inertia
- fuselage-frame-weight
- fuselage-stiffener-3d-geometry
- fuselage-stiffener-elastic-properties
- fuselage-stiffener-moments-of-inertia
- fuselage-stiffener-weight
- fuselage-skin-3d-geometry
- fuselage-skin-elastic-properties
- fuselage-skin-moments-of-inertia
- fuselage-skin-weight
- fuselage-aerodynamic-loads-cruise
- wing-attach-point-loads-cruise
- empennage-attach-point-loads-cruise

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-stiffener-deformations-cruise is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-cruise
wing-attach-point-loads-cruise
empennage-attach-point-loads-cruise

fuselage-skin-deformations-cruise is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-cruise
wing-attach-point-loads-cruise
empennage-attach-point-loads-cruise

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-jig-shape is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia

fuselage-frame-deformations-pull-up is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-pull-up
wing-attach-point-loads-pull-up
empennage-attach-point-loads-pull-up

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-stiffener-deformations-pull-up is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-pull-up
wing-attach-point-loads-pull-up
empennage-attach-point-loads-pull-up

fuselage-skin-deformations-pull-up is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-pull-up
wing-attach-point-loads-pull-up
empennage-attach-point-loads-pull-up

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-frame-deformations-turn is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-turn
wing-attach-point-loads-turn
empennage-attach-point-loads-turn

fuselage-stiffener-deformations-turn is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-turn
wing-attach-point-loads-turn
empennage-attach-point-loads-turn

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-skin-deformations-turn is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-turn
wing-attach-point-loads-turn
empennage-attach-point-loads-turn

fuselage-maneuvering-shape-turn is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-weight
fuselage-skin-3d-geometry
fuselage-skin-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-weight
fuselage-aerodynamic-loads-turn
wing-attach-point-loads-turn
empennage-attach-point-loads-turn

fuselage-frame-stresses-landing is a function of:

fuselage-frame-deformations-landing
fuselage-frame-elastic-properties

Table 144. Design Relationships in Subproblem 6-06, cont.

fuselage-stiffener-stresses-landing is a function of:

fuselage-stiffener-deformations-landing
fuselage-stiffener-elastic-properties

fuselage-skin-stresses-landing is a function of:

fuselage-skin-deformations-landing
fuselage-skin-elastic-properties

vertical-rib-deformations-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-stiffener-deformations-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-spar-deformations-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-spar-deformations-pull-up is a function of: (cont.)

vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-skin-deformations-pull-up is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-pull-up
vertical-aerodynamic-loads-pull-up
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

empennage-attach-point-loads-cruise is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-aerodynamic-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-rib-deformations-cruise is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-aerodynamic-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-rib-deformations-cruise is a function of: (cont.)

vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-stiffener-deformations-cruise is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-aerodynamic-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-spar-deformations-cruise is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-aerodynamic-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-skin-deformations-cruise is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-aerodynamic-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-skin-deformations-cruise is a function of: (cont.)

vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-jig-shape is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-cruise
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

empennage-attach-point-loads-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-rib-deformations-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-rib-deformations-turn is a function of: (cont.)

vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-stiffener-deformations-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-spar-deformations-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-skin-deformations-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-skin-deformations-turn is a function of: (cont.)

vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-maneuvering-shape-turn is a function of:

vertical-structural-arrangement
horizontal-attach-point-loads-turn
vertical-aerodynamic-loads-turn
vertical-rib-3d-geometry
vertical-rib-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-weight
vertical-skin-3d-geometry
vertical-skin-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-weight
vertical-stiffener-3d-geometry
vertical-stiffener-elastic-properties
vertical-stiffener-weight
vertical-stiffener-moments-of-inertia

vertical-rib-stresses-landing is a function of:

vertical-rib-deformations-landing
vertical-rib-elastic-properties

vertical-spar-stresses-landing is a function of:

vertical-spar-deformations-landing
vertical-spar-elastic-properties

Table 144. Design Relationships in Subproblem 6-06, cont.

vertical-skin-stresses-landing is a function of:

vertical-skin-deformations-landing
vertical-skin-elastic-properties

vertical-stiffener-stresses-landing is a function of:

vertical-stiffener-deformations-landing
vertical-stiffener-elastic-properties

horizontal-attach-point-loads-cruise is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-cruise
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-rib-deformations-cruise is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-cruise
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-stiffener-deformations-cruise is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-cruise
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-stiffener-deformations-cruise is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-spar-deformations-cruise is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-cruise
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-skin-deformations-cruise is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-cruise
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-jig-shape is a function of:

horizontal-structural-arrangement
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-rib-deformations-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-stiffener-deformations-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-stiffener-deformations-pull-up is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-spar-deformations-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-skin-deformations-pull-up is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-pull-up
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-attach-point-loads-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-attach-point-loads-turn is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-rib-deformations-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-stiffener-deformations-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-spar-deformations-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-spar-deformations-turn is a function of: (cont.)

horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-skin-deformations-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

Table 144. Design Relationships in Subproblem 6-06, cont.

horizontal-maneuvering-shape-turn is a function of:

horizontal-structural-arrangement
horizontal-aerodynamic-loads-turn
horizontal-rib-3d-geometry
horizontal-rib-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-weight
horizontal-skin-3d-geometry
horizontal-skin-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-elastic-properties
horizontal-stiffener-weight
horizontal-stiffener-moments-of-inertia

horizontal-rib-stresses-landing is a function of:

horizontal-rib-deformations-landing
horizontal-rib-elastic-properties

horizontal-spar-stresses-landing is a function of:

horizontal-spar-deformations-landing
horizontal-spar-elastic-properties

horizontal-skin-stresses-landing is a function of:

horizontal-skin-deformations-landing
horizontal-skin-elastic-properties

horizontal-stiffener-stresses-landing is a function of:

horizontal-stiffener-deformations-landing
horizontal-stiffener-elastic-properties

Table 144. Design Relationships in Subproblem 6-06, cont.

maneuvering-3d-shape-turn is a function of:

wing-maneuvering-shape-turn
fuselage-maneuvering-shape-turn
vertical-maneuvering-shape-turn
vertical-location
horizontal-location
horizontal-maneuvering-shape-turn

wing-aerodynamic-loads-turn is a function of:

maneuvering-3d-shape-turn

beta-turn is a function of:

aileron-3d-geometry
rudder-3d-geometry
i-z-z
i-z-y
maneuvering-3d-shape-turn
i-x-z

delta-a-turn is a function of:

aileron-3d-geometry
rudder-3d-geometry
i-z-z
i-z-y
maneuvering-3d-shape-turn
i-x-z

delta-r-turn is a function of:

aileron-3d-geometry
rudder-3d-geometry
i-z-z
i-z-y
maneuvering-3d-shape-turn
i-x-z

Table 145. Subproblem 6-06 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-12

maneuvering-3d-shape-pull-up

Output Parameters To Subproblem 5-12

maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 5-16

maneuvering-3d-shape-pull-up

Output Parameters To Subproblem 5-16

maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 5-14

wing-aerodynamic-loads-turn
horizontal-stiffener-moments-of-inertia
horizontal-stiffener-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-elastic-properties
vertical-stiffener-moments-of-inertia
vertical-stiffener-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-elastic-properties
wing-aerodynamic-loads-pull-up
aileron-3d-geometry
wing-maneuvering-shape-turn

Table 145. Subproblem 6-06 Interfaces, cont.

Input Parameters To Subproblem 5-14 (cont.)

wing-attach-point-loads-turn
wing-maneuvering-shape-pull-up
wing-attach-point-loads-pull-up
wing-attach-point-loads-cruise
vertical-stiffener-deformations-landing
vertical-rib-deformations-landing
vertical-spar-deformations-landing
vertical-skin-deformations-landing
horizontal-stiffener-deformations-landing
horizontal-rib-deformations-landing
horizontal-spar-deformations-landing
horizontal-skin-deformations-landing
fuselage-stiffener-deformations-landing
fuselage-frame-deformations-landing
fuselage-skin-deformations-landing
fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement
horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight

Table 145. Subproblem 6-06 Interfaces, cont.

Input Parameters To Subproblem 5-14 (cont.)

horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
horizontal-structural-arrangement
rudder-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 5-14

wing-aerodynamic-loads-turn
horizontal-stiffener-moments-of-inertia
horizontal-stiffener-elastic-properties
horizontal-skin-moments-of-inertia
horizontal-skin-elastic-properties
horizontal-spar-moments-of-inertia
horizontal-spar-elastic-properties
horizontal-rib-moments-of-inertia
horizontal-rib-elastic-properties
vertical-stiffener-moments-of-inertia
vertical-stiffener-elastic-properties
vertical-skin-moments-of-inertia
vertical-skin-elastic-properties
vertical-spar-moments-of-inertia
vertical-spar-elastic-properties
vertical-rib-moments-of-inertia
vertical-rib-elastic-properties
fuselage-skin-moments-of-inertia
fuselage-skin-elastic-properties
fuselage-stiffener-moments-of-inertia
fuselage-stiffener-elastic-properties
fuselage-frame-moments-of-inertia
fuselage-frame-elastic-properties
wing-aerodynamic-loads-pull-up
aileron-3d-geometry
wing-maneuvering-shape-turn

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 5-14 (cont.)

wing-attach-point-loads-turn
wing-maneuvering-shape-pull-up
wing-attach-point-loads-pull-up
wing-attach-point-loads-cruise
vertical-stiffener-deformations-landing
vertical-rib-deformations-landing
vertical-spar-deformations-landing
vertical-skin-deformations-landing
horizontal-stiffener-deformations-landing
horizontal-rib-deformations-landing
horizontal-spar-deformations-landing
horizontal-skin-deformations-landing
fuselage-stiffener-deformations-landing
fuselage-frame-deformations-landing
fuselage-skin-deformations-landing
fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement
horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 5-14 (cont.)

horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
horizontal-structural-arrangement
rudder-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Input Parameters To Subproblem 5-13

vertical-location

Input Parameters To Subproblem 5-15

horizontal-location

Input Parameters To Subproblem 5-09

fuselage-aerodynamic-loads-cruise

Input Parameters To Subproblem 5-11

vertical-aerodynamic-loads-cruise

Input Parameters To Subproblem 5-10

horizontal-aerodynamic-loads-cruise

Input Parameters To Subproblem 5-17

i-z-z
i-z-y
i-x-z

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 5-17

i-z-z
i-z-y
i-x-z

SUCCESSORS

Input Parameters To Subproblem 7-02

fuselage-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 7-03

horizontal-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 7-04

vertical-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Input Parameters To Subproblem 7-05

fuselage-frame-deformations-cruise
fuselage-frame-elastic-properties

Input Parameters To Subproblem 7-08

fuselage-frame-deformations-pull-up
fuselage-frame-elastic-properties

Input Parameters To Subproblem 7-11

fuselage-frame-deformations-turn
fuselage-frame-elastic-properties

Input Parameters To Subproblem 7-43

fuselage-frame-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-43

fuselage-frame-elastic-properties

Input Parameters To Subproblem 7-06

fuselage-stiffener-deformations-cruise
fuselage-stiffener-elastic-properties

Input Parameters To Subproblem 7-09

fuselage-stiffener-deformations-pull-up
fuselage-stiffener-elastic-properties

Input Parameters To Subproblem 7-12

fuselage-stiffener-deformations-turn
fuselage-stiffener-elastic-properties

Input Parameters To Subproblem 7-44

fuselage-stiffener-elastic-properties

Output Parameters To Subproblem 7-44

fuselage-stiffener-elastic-properties

Input Parameters To Subproblem 7-07

fuselage-skin-deformations-cruise
fuselage-skin-elastic-properties

Input Parameters To Subproblem 7-10

fuselage-skin-deformations-pull-up
fuselage-skin-elastic-properties

Input Parameters To Subproblem 7-13

fuselage-skin-deformations-turn
fuselage-skin-elastic-properties

Input Parameters To Subproblem 7-42

fuselage-skin-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-42

fuselage-skin-elastic-properties

Input Parameters To Subproblem 7-26

vertical-rib-deformations-cruise
vertical-rib-elastic-properties

Input Parameters To Subproblem 7-30

vertical-rib-deformations-pull-up
vertical-rib-elastic-properties

Input Parameters To Subproblem 7-34

vertical-rib-deformations-turn
vertical-rib-elastic-properties

Input Parameters To Subproblem 7-51

vertical-rib-elastic-properties

Output Parameters To Subproblem 7-51

vertical-rib-elastic-properties

Input Parameters To Subproblem 7-28

vertical-spar-deformations-cruise
vertical-spar-elastic-properties

Input Parameters To Subproblem 7-32

vertical-spar-deformations-pull-up
vertical-spar-elastic-properties

Input Parameters To Subproblem 7-36

vertical-spar-deformations-turn
vertical-spar-elastic-properties

Input Parameters To Subproblem 7-50

vertical-spar-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-50

vertical-spar-elastic-properties

Input Parameters To Subproblem 7-29

vertical-skin-deformations-cruise
vertical-skin-elastic-properties

Input Parameters To Subproblem 7-33

vertical-skin-deformations-pull-up
vertical-skin-elastic-properties

Input Parameters To Subproblem 7-37

vertical-skin-deformations-turn
vertical-skin-elastic-properties

Input Parameters To Subproblem 7-49

vertical-skin-elastic-properties

Output Parameters To Subproblem 7-49

vertical-skin-elastic-properties

Input Parameters To Subproblem 7-27

vertical-stiffener-deformations-cruise
vertical-stiffener-elastic-properties

Input Parameters To Subproblem 7-31

vertical-stiffener-deformations-pull-up
vertical-stiffener-elastic-properties

Input Parameters To Subproblem 7-35

vertical-stiffener-deformations-turn
vertical-stiffener-elastic-properties

Input Parameters To Subproblem 7-52

vertical-stiffener-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-52

vertical-stiffener-elastic-properties

Input Parameters To Subproblem 7-14

horizontal-rib-deformations-cruise
horizontal-rib-elastic-properties

Input Parameters To Subproblem 7-18

horizontal-rib-deformations-pull-up
horizontal-rib-elastic-properties

Input Parameters To Subproblem 7-22

horizontal-rib-deformations-turn
horizontal-rib-elastic-properties

Input Parameters To Subproblem 7-47

horizontal-rib-elastic-properties

Output Parameters To Subproblem 7-47

horizontal-rib-elastic-properties

Input Parameters To Subproblem 7-16

horizontal-spar-deformations-cruise
horizontal-spar-elastic-properties

Input Parameters To Subproblem 7-20

horizontal-spar-deformations-pull-up
horizontal-spar-elastic-properties

Input Parameters To Subproblem 7-24

horizontal-spar-deformations-turn
horizontal-spar-elastic-properties

Input Parameters To Subproblem 7-46

horizontal-spar-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-46

horizontal-spar-elastic-properties

Input Parameters To Subproblem 7-17

horizontal-skin-deformations-cruise
horizontal-skin-elastic-properties

Input Parameters To Subproblem 7-21

horizontal-skin-deformations-pull-up
horizontal-skin-elastic-properties

Input Parameters To Subproblem 7-25

horizontal-skin-deformations-turn
horizontal-skin-elastic-properties

Input Parameters To Subproblem 7-45

horizontal-skin-elastic-properties

Output Parameters To Subproblem 7-45

horizontal-skin-elastic-properties

Input Parameters To Subproblem 7-15

horizontal-stiffener-deformations-cruise
horizontal-stiffener-elastic-properties

Input Parameters To Subproblem 7-19

horizontal-stiffener-deformations-pull-up
horizontal-stiffener-elastic-properties

Input Parameters To Subproblem 7-23

horizontal-stiffener-deformations-turn
horizontal-stiffener-elastic-properties

Input Parameters To Subproblem 7-48

horizontal-stiffener-elastic-properties

Table 145. Subproblem 6-06 Interfaces, cont.

Output Parameters To Subproblem 7-48

horizontal-stiffener-elastic-properties

Input Parameters To Subproblem 7-53

fuselage-aerodynamic-loads-turn
maneuvering-3d-shape-turn

Input Parameters To Subproblem 7-55

vertical-aerodynamic-loads-turn
maneuvering-3d-shape-turn

Input Parameters To Subproblem 7-54

horizontal-aerodynamic-loads-turn
maneuvering-3d-shape-turn

Table 146. Design Relationships in Subproblem 6-07

rudder-actuator-moments-of-inertia is a function of:

rudder-actuator-geometry

rudder-actuator-normal-mode-shapes is a function of:

rudder-actuator-geometry
rudder-actuator-moments-of-inertia
rudder-actuator-elastic-properties

rudder-actuator-normal-mode-frequencies is a function of:

rudder-actuator-geometry
rudder-actuator-moments-of-inertia
rudder-actuator-elastic-properties

Table 146. Design Relationships in Subproblem 6-07, cont.

rudder-flutter-speed is a function of:

rudder-actuator-normal-mode-frequencies
rudder-quasi-steady-aerodynamic-loads

rudder-actuator-elastic-properties is an independent design paramete

Table 147. Subproblem 6-07 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

rudder-actuator-normal-mode-shapes
rudder-quasi-steady-aerodynamic-loads
rudder-actuator-geometry

Table 148. Design Relationships in Subproblem 6-08

rudder-max-hinge-moment is a function of:

max-airplane-beta
max-rudder-delta-r
rudder-3d-geometry

max-airplane-beta is an independent design parameter

max-rudder-delta-r is an independent design parameter

Table 149. Subproblem 6-08 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

rudder-max-hinge-moment
rudder-3d-geometry

Table 150. Design Relationships in Subproblem 6-09

wing-flutter-speed is a function of:

aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

aircraft-quasi-steady-aerodynamic-loads-flight is a function of:

aircraft-normal-mode-frequencies-flight
aircraft-normal-mode-shapes-flight

empennage-flutter-speed is a function of:

aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

wing-skin-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

Table 150. Design Relationships in Subproblem 6-09, cont.

wing-spar-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

wing-rib-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

wing-stiffener-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

fuselage-skin-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

fuselage-frame-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

fuselage-stiffener-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

Table 150. Design Relationships in Subproblem 6-09, cont.

horizontal-skin-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

horizontal-spar-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

horizontal-rib-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

horizontal-stiffener-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

vertical-skin-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

vertical-spar-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

Table 150. Design Relationships in Subproblem 6-09, cont.

vertical-rib-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

vertical-stiffener-deformations-gust is a function of:

gust-dynamic-loads
aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-shapes-flight
aircraft-normal-mode-frequencies-flight

gust-dynamic-loads is an independent design parameter

Table 151. Subproblem 6-09 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

aircraft-quasi-steady-aerodynamic-loads-flight
aircraft-normal-mode-frequencies-flight
aircraft-normal-mode-shapes-flight

SUCCESSORS

Input Parameters To Subproblem 7-38

wing-skin-deformations-gust

Output Parameters To Subproblem 7-38

wing-skin-deformations-gust

Table 151. Subproblem 6-09 Interfaces, cont.

Input Parameters To Subproblem 7-39

wing-spar-deformations-gust

Output Parameters To Subproblem 7-39

wing-spar-deformations-gust

Input Parameters To Subproblem 7-40

wing-rib-deformations-gust

Output Parameters To Subproblem 7-40

wing-rib-deformations-gust

Input Parameters To Subproblem 7-41

wing-stiffener-deformations-gust

Output Parameters To Subproblem 7-41

wing-stiffener-deformations-gust

Input Parameters To Subproblem 7-42

fuselage-skin-deformations-gust

Output Parameters To Subproblem 7-42

fuselage-skin-deformations-gust

Input Parameters To Subproblem 7-43

fuselage-frame-deformations-gust

Output Parameters To Subproblem 7-43

fuselage-frame-deformations-gust

Input Parameters To Subproblem 7-44

fuselage-stiffener-deformations-gust

Table 151. Subproblem 6-09 Interfaces, cont.

Output Parameters To Subproblem 7-44

fuselage-stiffener-deformations-gust

Input Parameters To Subproblem 7-45

horizontal-skin-deformations-gust

Output Parameters To Subproblem 7-45

horizontal-skin-deformations-gust

Input Parameters To Subproblem 7-46

horizontal-spar-deformations-gust

Output Parameters To Subproblem 7-46

horizontal-spar-deformations-gust

Input Parameters To Subproblem 7-47

horizontal-rib-deformations-gust

Output Parameters To Subproblem 7-47

horizontal-rib-deformations-gust

Input Parameters To Subproblem 7-48

horizontal-stiffener-deformations-gust

Output Parameters To Subproblem 7-48

horizontal-stiffener-deformations-gust

Input Parameters To Subproblem 7-49

vertical-skin-deformations-gust

Output Parameters To Subproblem 7-49

vertical-skin-deformations-gust

Table 151. Subproblem 6-09 Interfaces, cont.

Input Parameters To Subproblem 7-50

vertical-spar-deformations-gust

Output Parameters To Subproblem 7-50

vertical-spar-deformations-gust

Input Parameters To Subproblem 7-51

vertical-rib-deformations-gust

Output Parameters To Subproblem 7-51

vertical-rib-deformations-gust

Input Parameters To Subproblem 7-52

vertical-stiffener-deformations-gust

Output Parameters To Subproblem 7-52

vertical-stiffener-deformations-gust

Table 152. Design Relationships in Subproblem 6-10

nose-landing-gear-design-concept is an independent design parameter

nose-landing-gear-kinematics is a function of:

nose-landing-gear-design-concept
nose-landing-gear-3d-geometry

Table 153. Subproblem 6-10 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry
nose-landing-gear-design-concept

Output Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry
nose-landing-gear-design-concept

Input Parameters To Subproblem 5-03

nose-landing-gear-design-concept

Table 154. Design Relationships in Subproblem 6-11

wing-rib-stresses-cruise is a function of:

wing-rib-deformations-cruise
wing-rib-elastic-properties

wing-rib-elastic-properties is an independent design parameter

Table 154. Design Relationships in Subproblem 6-11, cont.

wing-jig-shape is a function of:

wing-structural-arrangement
wing-rib-3d-geometry
wing-rib-elastic-properties
wing-rib-moments-of-inertia
wing-spar-3d-geometry
wing-spar-elastic-properties
wing-spar-moments-of-inertia
wing-skin-3d-geometry
wing-skin-elastic-properties
wing-skin-moments-of-inertia
wing-stiffener-3d-geometry
wing-stiffener-elastic-properties
wing-stiffener-moments-of-inertia

wing-rib-stresses-pull-up is a function of:

wing-rib-deformations-pull-up
wing-rib-elastic-properties

wing-rib-stresses-turn is a function of:

wing-rib-deformations-turn
wing-rib-elastic-properties

wing-rib-stresses-landing is a function of:

wing-rib-deformations-landing
wing-rib-elastic-properties

wing-rib-moments-of-inertia is an independent design parameter

wing-spar-elastic-properties is an independent design parameter

wing-spar-moments-of-inertia is an independent design parameter

wing-skin-elastic-properties is an independent design parameter

Table 154. Design Relationships in Subproblem 6-11, cont.

wing-skin-moments-of-inertia is an independent design parameter

wing-stiffener-elastic-properties is an independent design parameter

wing-stiffener-moments-of-inertia is an independent design parameter

wing-spar-stresses-cruise is a function of:

wing-spar-deformations-cruise
wing-spar-elastic-properties

wing-spar-stresses-pull-up is a function of:

wing-spar-deformations-pull-up
wing-spar-elastic-properties

wing-spar-stresses-turn is a function of:

wing-spar-deformations-turn
wing-spar-elastic-properties

wing-spar-stresses-landing is a function of:

wing-spar-deformations-landing
wing-spar-elastic-properties

wing-skin-stresses-cruise is a function of:

wing-skin-deformations-cruise
wing-skin-elastic-properties

wing-skin-stresses-pull-up is a function of:

wing-skin-deformations-pull-up
wing-skin-elastic-properties

Table 154. Design Relationships in Subproblem 6-11, cont.

wing-skin-stresses-turn is a function of:

wing-skin-deformations-turn
wing-skin-elastic-properties

wing-skin-stresses-landing is a function of:

wing-skin-deformations-landing
wing-skin-elastic-properties

wing-stiffener-stresses-cruise is a function of:

wing-stiffener-deformations-cruise
wing-stiffener-elastic-properties

wing-stiffener-stresses-pull-up is a function of:

wing-stiffener-deformations-pull-up
wing-stiffener-elastic-properties

wing-stiffener-stresses-turn is a function of:

wing-stiffener-deformations-turn
wing-stiffener-elastic-properties

wing-stiffener-stresses-landing is a function of:

wing-stiffener-deformations-landing
wing-stiffener-elastic-properties

Table 155. Subproblem 6-11 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

wing-stiffener-moments-of-inertia
wing-stiffener-elastic-properties
wing-skin-moments-of-inertia
wing-skin-elastic-properties
wing-spar-moments-of-inertia
wing-spar-elastic-properties
wing-rib-moments-of-inertia
wing-rib-elastic-properties
wing-skin-deformations-turn
wing-spar-deformations-turn
wing-stiffener-deformations-turn
wing-rib-deformations-turn
wing-skin-deformations-pull-up
wing-spar-deformations-pull-up
wing-stiffener-deformations-pull-up
wing-rib-deformations-pull-up
wing-skin-deformations-cruise
wing-spar-deformations-cruise
wing-stiffener-deformations-cruise
wing-rib-deformations-cruise
wing-stiffener-deformations-landing
wing-rib-deformations-landing
wing-spar-deformations-landing
wing-skin-deformations-landing

Table 155. Subproblem 6-11 Interfaces, cont.

Output Parameters To Subproblem 5-14 (cont.)

wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

SUCCESSORS

Input Parameters To Subproblem 7-40

wing-rib-elastic-properties

Output Parameters To Subproblem 7-40

wing-rib-elastic-properties

Input Parameters To Subproblem 7-39

wing-spar-elastic-properties

Output Parameters To Subproblem 7-39

wing-spar-elastic-properties

Input Parameters To Subproblem 7-38

wing-skin-elastic-properties

Output Parameters To Subproblem 7-38

wing-skin-elastic-properties

Input Parameters To Subproblem 7-41

wing-stiffener-elastic-properties

Output Parameters To Subproblem 7-41

wing-stiffener-elastic-properties

Table 156. Design Relationships in Subproblem 6-12

vertical-moments-of-inertia is a function of:

vertical-structural-arrangement
vertical-rib-3d-geometry
vertical-rib-weight
vertical-spar-3d-geometry
vertical-spar-weight
vertical-stiffener-3d-geometry
vertical-stiffener-weight
vertical-skin-3d-geometry
vertical-skin-weight

Table 157. Subproblem 6-12 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

vertical-moments-of-inertia

Output Parameters To Subproblem 5-17

vertical-moments-of-inertia

Input Parameters To Subproblem 5-14

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 157. Subproblem 6-12 Interfaces, cont.

Output Parameters To Subproblem 5-14

vertical-stiffener-weight
vertical-spar-weight
vertical-rib-weight
vertical-stiffener-3d-geometry
vertical-spar-3d-geometry
vertical-rib-3d-geometry
vertical-structural-arrangement
vertical-skin-weight
vertical-skin-3d-geometry

Table 158. Design Relationships in Subproblem 6-13

main-landing-gear-moments-of-inertia is a function of:

main-landing-gear-3d-geometry

Table 159. Subproblem 6-13 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

main-landing-gear-moments-of-inertia

Output Parameters To Subproblem 5-17

main-landing-gear-moments-of-inertia

Input Parameters To Subproblem 5-14

main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry

Output Parameters To Subproblem 5-14

main-landing-gear-moments-of-inertia
main-landing-gear-3d-geometry

Table 160. Design Relationships in Subproblem 6-14

fuselage-moments-of-inertia is a function of:

fuselage-structural-arrangement
fuselage-frame-3d-geometry
fuselage-frame-weight
fuselage-skin-3d-geometry
fuselage-skin-weight
fuselage-stiffener-3d-geometry
fuselage-stiffener-weight

Table 161. Subproblem 6-14 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

fuselage-moments-of-inertia

Output Parameters To Subproblem 5-17

fuselage-moments-of-inertia

Input Parameters To Subproblem 5-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Table 161. Subproblem 6-14 Interfaces, cont.

Output Parameters To Subproblem 5-14

fuselage-skin-weight
fuselage-skin-3d-geometry
fuselage-stiffener-weight
fuselage-stiffener-3d-geometry
fuselage-frame-weight
fuselage-frame-3d-geometry
fuselage-structural-arrangement

Table 162. Design Relationships in Subproblem 6-15

wing-moments-of-inertia is a function of:

wing-structural-arrangement
wing-rib-3d-geometry
wing-rib-weight
wing-spar-3d-geometry
wing-spar-weight
wing-stiffener-3d-geometry
wing-stiffener-weight
wing-skin-3d-geometry
wing-skin-weight

Table 163. Subproblem 6-15 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

wing-moments-of-inertia

Output Parameters To Subproblem 5-17

wing-moments-of-inertia

Table 163. Subproblem 6-15 Interfaces, cont.

Input Parameters To Subproblem 5-14

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Output Parameters To Subproblem 5-14

wing-skin-weight
wing-stiffener-weight
wing-spar-weight
wing-rib-weight
wing-skin-3d-geometry
wing-stiffener-3d-geometry
wing-spar-3d-geometry
wing-rib-3d-geometry
wing-structural-arrangement

Table 164. Design Relationships in Subproblem 6-16

horizontal-moments-of-inertia is a function of:

horizontal-structural-arrangement
horizontal-rib-3d-geometry
horizontal-rib-weight
horizontal-spar-3d-geometry
horizontal-spar-weight
horizontal-stiffener-3d-geometry
horizontal-stiffener-weight
horizontal-skin-3d-geometry
horizontal-skin-weight

Table 165. Subproblem 6-16 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

horizontal-moments-of-inertia

Output Parameters To Subproblem 5-17

horizontal-moments-of-inertia

Input Parameters To Subproblem 5-14

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Output Parameters To Subproblem 5-14

horizontal-skin-weight
horizontal-stiffener-weight
horizontal-spar-weight
horizontal-rib-weight
horizontal-skin-3d-geometry
horizontal-stiffener-3d-geometry
horizontal-spar-3d-geometry
horizontal-rib-3d-geometry
horizontal-structural-arrangement

Table 166. Design Relationships in Subproblem 6-17

nose-landing-gear-moments-of-inertia is a function of:

nose-landing-gear-3d-geometry

Table 167. Subproblem 6-17 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-17

nose-landing-gear-moments-of-inertia

Output Parameters To Subproblem 5-17

nose-landing-gear-moments-of-inertia

Input Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry

Output Parameters To Subproblem 5-19

nose-landing-gear-3d-geometry

Table 168. Design Relationships in Subproblem 6-18

load-factor is an independent design parameter

Table 169. Subproblem 6-18 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-12

load-factor

Output Parameters To Subproblem 5-12

load-factor

Input Parameters To Subproblem 5-16

load-factor

Output Parameters To Subproblem 5-16

load-factor

Table 170. Design Relationships in Subproblem 6-19

main-landing-gear-kinematics is a function of:

main-landing-gear-design-concept
main-landing-gear-3d-geometry

Table 171. Subproblem 6-19 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

main-landing-gear-design-concept
main-landing-gear-3d-geometry

Table 172. Design Relationships in Subproblem 6-20

elevator-actuator-moments-of-inertia is a function of:

elevator-actuator-geometry

elevator-actuator-normal-mode-shapes is a function of:

elevator-actuator-geometry
elevator-actuator-moments-of-inertia
elevator-actuator-elastic-properties

elevator-actuator-normal-mode-frequencies is a function of:

elevator-actuator-geometry
elevator-actuator-moments-of-inertia
elevator-actuator-elastic-properties

elevator-flutter-speed is a function of:

elevator-actuator-normal-mode-frequencies
elevator-quasi-steady-aerodynamic-loads

elevator-actuator-elastic-properties is an independent design parameter

Table 173. Subproblem 6-20 Interfaces

PREDECESSORS

Input Parameters To Subproblem 5-14

elevator-actuator-geometry

Output Parameters To Subproblem 5-14

elevator-actuator-geometry

Table 173. Subproblem 6-20 Interfaces, cont.

Input Parameters To Subproblem 5-18

elevator-quasi-steady-aerodynamic-loads
elevator-actuator-normal-mode-shapes

Table 174. Design Relationships in Subproblem 6-21

aileron-actuator-moments-of-inertia is a function of:

aileron-actuator-geometry

aileron-actuator-normal-mode-shapes is a function of:

aileron-actuator-geometry
aileron-actuator-moments-of-inertia
aileron-actuator-elastic-properties

aileron-actuator-normal-mode-frequencies is a function of:

aileron-actuator-geometry
aileron-actuator-moments-of-inertia
aileron-actuator-elastic-properties

aileron-flutter-speed is a function of:

aileron-actuator-normal-mode-frequencies
aileron-quasi-steady-aerodynamic-loads

aileron-actuator-elastic-properties is an independent design parameter

Table 175. Subproblem 6-21 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

aileron-actuator-normal-mode-shapes
aileron-quasi-steady-aerodynamic-loads
aileron-actuator-geometry

Table 176. Design Relationships in Subproblem 6-22

aileron-max-hinge-moment is a function of:

max-wing-alpha
max-aileron-delta-e
aileron-3d-geometry

max-wing-alpha is an independent design parameter

max-aileron-delta-e is an independent design parameter

Table 177. Subproblem 6-22 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

aileron-max-hinge-moment
aileron-3d-geometry

Table 178. Design Relationships in Subproblem 6-23

aircraft-quasi-steady-aerodynamic-loads-landing is a function of:

aircraft-normal-mode-frequencies-landing
aircraft-normal-mode-shapes-landing

Table 179. Subproblem 6-23 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

aircraft-quasi-steady-aerodynamic-loads-landing
aircraft-normal-mode-frequencies-landing
aircraft-normal-mode-shapes-landing

Table 180. Design Relationships in Subproblem 6-24

wing-cp-distribution is a function of:

wing-3d-shape

Table 181. Subproblem 6-24 Interfaces

PREDECESSORS

Output Parameters To Subproblem 5-14

wing-3d-shape

Table 182. Design Relationships in Subproblem 7-01

inlet-3d-geometry is an independent design parameter

Table 183. Subproblem 7-01 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-02

inlet-3d-geometry

Input Parameters To Subproblem 6-03

inlet-3d-geometry

Input Parameters To Subproblem 6-04

inlet-3d-geometry

Output Parameters To Subproblem 6-04

inlet-3d-geometry

Table 184. Design Relationships in Subproblem 7-02

fuselage-aerodynamic-loads-pull-up is a function of:

maneuvering-3d-shape-pull-up

Table 185. Subproblem 7-02 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Table 186. Design Relationships in Subproblem 7-03

horizontal-aerodynamic-loads-pull-up is a function of:

maneuvering-3d-shape-pull-up

Table 187. Subproblem 7-03 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Table 188. Design Relationships in Subproblem 7-04

vertical-aerodynamic-loads-pull-up is a function of:

maneuvering-3d-shape-pull-up

Table 189. Subproblem 7-04 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-aerodynamic-loads-pull-up
maneuvering-3d-shape-pull-up

Table 190. Design Relationships in Subproblem 7-05

fuselage-frame-stresses-cruise is a function of:

fuselage-frame-deformations-cruise
fuselage-frame-elastic-properties

Table 191. Subproblem 7-05 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-frame-deformations-cruise
fuselage-frame-elastic-properties

Table 192. Design Relationships in Subproblem 7-06

fuselage-stiffener-stresses-cruise is a function of:

fuselage-stiffener-deformations-cruise
fuselage-stiffener-elastic-properties

Table 193. Subproblem 7-06 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-stiffener-deformations-cruise
fuselage-stiffener-elastic-properties

Table 194. Design Relationships in Subproblem 7-07

fuselage-skin-stresses-cruise is a function of:

fuselage-skin-deformations-cruise
fuselage-skin-elastic-properties

Table 195. Subproblem 7-07 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-skin-deformations-cruise
fuselage-skin-elastic-properties

Table 196. Design Relationships in Subproblem 7-08

fuselage-frame-stresses-pull-up is a function of:

fuselage-frame-deformations-pull-up
fuselage-frame-elastic-properties

Table 197. Subproblem 7-08 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-frame-deformations-pull-up
fuselage-frame-elastic-properties

Table 198. Design Relationships in Subproblem 7-09

fuselage-stiffener-stresses-pull-up is a function of:

fuselage-stiffener-deformations-pull-up
fuselage-stiffener-elastic-properties

Table 199. Subproblem 7-09 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-stiffener-deformations-pull-up
fuselage-stiffener-elastic-properties

Table 200. Design Relationships in Subproblem 7-10

fuselage-skin-stresses-pull-up is a function of:

fuselage-skin-deformations-pull-up
fuselage-skin-elastic-properties

Table 201. Subproblem 7-10 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-skin-deformations-pull-up
fuselage-skin-elastic-properties

Table 202. Design Relationships in Subproblem 7-11

fuselage-frame-stresses-turn is a function of:

fuselage-frame-deformations-turn
fuselage-frame-elastic-properties

Table 203. Subproblem 7-11 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-frame-deformations-turn
fuselage-frame-elastic-properties

Table 204. Design Relationships in Subproblem 7-12

fuselage-stiffener-stresses-turn is a function of:

fuselage-stiffener-deformations-turn
fuselage-stiffener-elastic-properties

Table 205. Subproblem 7-12 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-stiffener-deformations-turn
fuselage-stiffener-elastic-properties

Table 206. Design Relationships in Subproblem 7-13

fuselage-skin-stresses-turn is a function of:

fuselage-skin-deformations-turn
fuselage-skin-elastic-properties

Table 207. Subproblem 7-13 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-skin-deformations-turn
fuselage-skin-elastic-properties

Table 208. Design Relationships in Subproblem 7-14

horizontal-rib-stresses-cruise is a function of:

horizontal-rib-deformations-cruise
horizontal-rib-elastic-properties

Table 209. Subproblem 7-14 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-rib-deformations-cruise
horizontal-rib-elastic-properties

Table 210. Design Relationships in Subproblem 7-15

horizontal-stiffener-stresses-cruise is a function of:

horizontal-stiffener-deformations-cruise
horizontal-stiffener-elastic-properties

Table 211. Subproblem 7-15 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-stiffener-deformations-cruise
horizontal-stiffener-elastic-properties

Table 212. Design Relationships in Subproblem 7-16

horizontal-spar-stresses-cruise is a function of:

horizontal-spar-deformations-cruise
horizontal-spar-elastic-properties

Table 213. Subproblem 7-16 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-spar-deformations-cruise
horizontal-spar-elastic-properties

Table 214. Design Relationships in Subproblem 7-17

horizontal-skin-stresses-cruise is a function of:

horizontal-skin-deformations-cruise
horizontal-skin-elastic-properties

Table 215. Subproblem 7-17 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-skin-deformations-cruise
horizontal-skin-elastic-properties

Table 216. Design Relationships in Subproblem 7-18

horizontal-rib-stresses-pull-up is a function of:

horizontal-rib-deformations-pull-up
horizontal-rib-elastic-properties

Table 217. Subproblem 7-18 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-rib-deformations-pull-up
horizontal-rib-elastic-properties

Table 218. Design Relationships in Subproblem 7-19

horizontal-stiffener-stresses-pull-up is a function of:

horizontal-stiffener-deformations-pull-up
horizontal-stiffener-elastic-properties

Table 219. Subproblem 7-19 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-stiffener-deformations-pull-up
horizontal-stiffener-elastic-properties

Table 220. Design Relationships in Subproblem 7-20

horizontal-spar-stresses-pull-up is a function of:

horizontal-spar-deformations-pull-up
horizontal-spar-elastic-properties

Table 221. Subproblem 7-20 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-spar-deformations-pull-up
horizontal-spar-elastic-properties

Table 222. Design Relationships in Subproblem 7-21

horizontal-skin-stresses-pull-up is a function of:

horizontal-skin-deformations-pull-up
horizontal-skin-elastic-properties

Table 223. Subproblem 7-21 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-skin-deformations-pull-up
horizontal-skin-elastic-properties

Table 224. Design Relationships in Subproblem 7-22

horizontal-rib-stresses-turn is a function of:

horizontal-rib-deformations-turn
horizontal-rib-elastic-properties

Table 225. Subproblem 7-22 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-rib-deformations-turn
horizontal-rib-elastic-properties

Table 226. Design Relationships in Subproblem 7-23

horizontal-stiffener-stresses-turn is a function of:

horizontal-stiffener-deformations-turn
horizontal-stiffener-elastic-properties

Table 227. Subproblem 7-23 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-stiffener-deformations-turn
horizontal-stiffener-elastic-properties

Table 228. Design Relationships in Subproblem 7-24

horizontal-spar-stresses-turn is a function of:

horizontal-spar-deformations-turn
horizontal-spar-elastic-properties

Table 229. Subproblem 7-24 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-spar-deformations-turn
horizontal-spar-elastic-properties

Table 230. Design Relationships in Subproblem 7-25

horizontal-skin-stresses-turn is a function of:

horizontal-skin-deformations-turn
horizontal-skin-elastic-properties

Table 231. Subproblem 7-25 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-skin-deformations-turn
horizontal-skin-elastic-properties

Table 232. Design Relationships in Subproblem 7-26

vertical-rib-stresses-cruise is a function of:

vertical-rib-deformations-cruise
vertical-rib-elastic-properties

Table 233. Subproblem 7-26 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-rib-deformations-cruise
vertical-rib-elastic-properties

Table 234. Design Relationships in Subproblem 7-27

vertical-stiffener-stresses-cruise is a function of:

vertical-stiffener-deformations-cruise
vertical-stiffener-elastic-properties

Table 235. Subproblem 7-27 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-stiffener-deformations-cruise
vertical-stiffener-elastic-properties

Table 236. Design Relationships in Subproblem 7-28

vertical-spar-stresses-cruise is a function of:

vertical-spar-deformations-cruise
vertical-spar-elastic-properties

Table 237. Subproblem 7-28 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-spar-deformations-cruise
vertical-spar-elastic-properties

Table 238. Design Relationships in Subproblem 7-29

vertical-skin-stresses-cruise is a function of:

vertical-skin-deformations-cruise
vertical-skin-elastic-properties

Table 239. Subproblem 7-29 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-skin-deformations-cruise
vertical-skin-elastic-properties

Table 240. Design Relationships in Subproblem 7-30

vertical-rib-stresses-pull-up is a function of:

vertical-rib-deformations-pull-up
vertical-rib-elastic-properties

Table 241. Subproblem 7-30 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-rib-deformations-pull-up
vertical-rib-elastic-properties

Table 242. Design Relationships in Subproblem 7-31

vertical-stiffener-stresses-pull-up is a function of:

vertical-stiffener-deformations-pull-up
vertical-stiffener-elastic-properties

Table 243. Subproblem 7-31 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-stiffener-deformations-pull-up
vertical-stiffener-elastic-properties

Table 244. Design Relationships in Subproblem 7-32

vertical-spar-stresses-pull-up is a function of:

vertical-spar-deformations-pull-up
vertical-spar-elastic-properties

Table 245. Subproblem 7-32 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-spar-deformations-pull-up
vertical-spar-elastic-properties

Table 246. Design Relationships in Subproblem 7-33

vertical-skin-stresses-pull-up is a function of:

vertical-skin-deformations-pull-up
vertical-skin-elastic-properties

Table 247. Subproblem 7-33 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-skin-deformations-pull-up
vertical-skin-elastic-properties

Table 248. Design Relationships in Subproblem 7-34

vertical-rib-stresses-turn is a function of:

vertical-rib-deformations-turn
vertical-rib-elastic-properties

Table 249. Subproblem 7-34 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-rib-deformations-turn
vertical-rib-elastic-properties

Table 250. Design Relationships in Subproblem 7-35

vertical-stiffener-stresses-turn is a function of:

vertical-stiffener-deformations-turn
vertical-stiffener-elastic-properties

Table 251. Subproblem 7-35 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-stiffener-deformations-turn
vertical-stiffener-elastic-properties

Table 252. Design Relationships in Subproblem 7-36

vertical-spar-stresses-turn is a function of:

vertical-spar-deformations-turn
vertical-spar-elastic-properties

Table 253. Subproblem 7-36 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-spar-deformations-turn
vertical-spar-elastic-properties

Table 254. Design Relationships in Subproblem 7-37

vertical-skin-stresses-turn is a function of:

vertical-skin-deformations-turn
vertical-skin-elastic-properties

Table 255. Subproblem 7-37 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-skin-deformations-turn
vertical-skin-elastic-properties

Table 256. Design Relationships in Subproblem 7-38

wing-skin-stresses-gust is a function of:

wing-skin-deformations-gust
wing-skin-elastic-properties

Table 257. Subproblem 7-38 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

wing-skin-deformations-gust

Output Parameters To Subproblem 6-09

wing-skin-deformations-gust

Input Parameters To Subproblem 6-11

wing-skin-elastic-properties

Output Parameters To Subproblem 6-11

wing-skin-elastic-properties

Table 258. Design Relationships in Subproblem 7-39

wing-spar-stresses-gust is a function of:

wing-spar-deformations-gust
wing-spar-elastic-properties

Table 259. Subproblem 7-39 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

wing-spar-deformations-gust

Output Parameters To Subproblem 6-09

wing-spar-deformations-gust

Table 259. Subproblem 7-39 Interfaces, cont.

Input Parameters To Subproblem 6-11

wing-spar-elastic-properties

Output Parameters To Subproblem 6-11

wing-spar-elastic-properties

Table 260. Design Relationships in Subproblem 7-40

wing-rib-stresses-gust is a function of:

wing-rib-deformations-gust
wing-rib-elastic-properties

Table 261. Subproblem 7-40 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

wing-rib-deformations-gust

Output Parameters To Subproblem 6-09

wing-rib-deformations-gust

Input Parameters To Subproblem 6-11

wing-rib-elastic-properties

Output Parameters To Subproblem 6-11

wing-rib-elastic-properties

Table 262. Design Relationships in Subproblem 7-41

wing-stiffener-stresses-gust is a function of:

wing-stiffener-deformations-gust
wing-stiffener-elastic-properties

Table 263. Subproblem 7-41 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

wing-stiffener-deformations-gust

Output Parameters To Subproblem 6-09

wing-stiffener-deformations-gust

Input Parameters To Subproblem 6-11

wing-stiffener-elastic-properties

Output Parameters To Subproblem 6-11

wing-stiffener-elastic-properties

Table 264. Design Relationships in Subproblem 7-42

fuselage-skin-stresses-gust is a function of:

fuselage-skin-deformations-gust
fuselage-skin-elastic-properties

Table 265. Subproblem 7-42 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

fuselage-skin-deformations-gust

Output Parameters To Subproblem 6-09

fuselage-skin-deformations-gust

Input Parameters To Subproblem 6-06

fuselage-skin-elastic-properties

Output Parameters To Subproblem 6-06

fuselage-skin-elastic-properties

Table 266. Design Relationships in Subproblem 7-43

fuselage-frame-stresses-gust is a function of:

fuselage-frame-deformations-gust
fuselage-frame-elastic-properties

Table 267. Subproblem 7-43 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

fuselage-frame-deformations-gust

Output Parameters To Subproblem 6-09

fuselage-frame-deformations-gust

Table 267. Subproblem 7-43 Interfaces, cont.

Input Parameters To Subproblem 6-06

fuselage-frame-elastic-properties

Output Parameters To Subproblem 6-06

fuselage-frame-elastic-properties

Table 268. Design Relationships in Subproblem 7-44

fuselage-stiffener-stresses-gust is a function of:

fuselage-stiffener-deformations-gust
fuselage-stiffener-elastic-properties

Table 269. Subproblem 7-44 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

fuselage-stiffener-deformations-gust

Output Parameters To Subproblem 6-09

fuselage-stiffener-deformations-gust

Input Parameters To Subproblem 6-06

fuselage-stiffener-elastic-properties

Output Parameters To Subproblem 6-06

fuselage-stiffener-elastic-properties

Table 270. Design Relationships in Subproblem 7-45

horizontal-skin-stresses-gust is a function of:

horizontal-skin-deformations-gust
horizontal-skin-elastic-properties

Table 271. Subproblem 7-45 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

horizontal-skin-deformations-gust

Output Parameters To Subproblem 6-09

horizontal-skin-deformations-gust

Input Parameters To Subproblem 6-06

horizontal-skin-elastic-properties

Output Parameters To Subproblem 6-06

horizontal-skin-elastic-properties

Table 272. Design Relationships in Subproblem 7-46

horizontal-spar-stresses-gust is a function of:

horizontal-spar-deformations-gust
horizontal-spar-elastic-properties

Table 273. Subproblem 7-46 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

horizontal-spar-deformations-gust

Output Parameters To Subproblem 6-09

horizontal-spar-deformations-gust

Input Parameters To Subproblem 6-06

horizontal-spar-elastic-properties

Output Parameters To Subproblem 6-06

horizontal-spar-elastic-properties

Table 274. Design Relationships in Subproblem 7-47

horizontal-rib-stresses-gust is a function of:

horizontal-rib-deformations-gust
horizontal-rib-elastic-properties

Table 275. Subproblem 7-47 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

horizontal-rib-deformations-gust

Output Parameters To Subproblem 6-09

horizontal-rib-deformations-gust

Table 275. Subproblem 7-47 Interfaces, cont.

Input Parameters To Subproblem 6-06

horizontal-rib-elastic-properties

Output Parameters To Subproblem 6-06

horizontal-rib-elastic-properties

Table 276. Design Relationships in Subproblem 7-48

horizontal-stiffener-stresses-gust is a function of:

horizontal-stiffener-deformations-gust
horizontal-stiffener-elastic-properties

Table 277. Subproblem 7-48 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

horizontal-stiffener-deformations-gust

Output Parameters To Subproblem 6-09

horizontal-stiffener-deformations-gust

Input Parameters To Subproblem 6-06

horizontal-stiffener-elastic-properties

Output Parameters To Subproblem 6-06

horizontal-stiffener-elastic-properties

Table 278. Design Relationships in Subproblem 7-49

vertical-skin-stresses-gust is a function of:

vertical-skin-deformations-gust
vertical-skin-elastic-properties

Table 279. Subproblem 7-49 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

vertical-skin-deformations-gust

Output Parameters To Subproblem 6-09

vertical-skin-deformations-gust

Input Parameters To Subproblem 6-06

vertical-skin-elastic-properties

Output Parameters To Subproblem 6-06

vertical-skin-elastic-properties

Table 280. Design Relationships in Subproblem 7-50

vertical-spar-stresses-gust is a function of:

vertical-spar-deformations-gust
vertical-spar-elastic-properties

Table 281. Subproblem 7-50 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

vertical-spar-deformations-gust

Output Parameters To Subproblem 6-09

vertical-spar-deformations-gust

Input Parameters To Subproblem 6-06

vertical-spar-elastic-properties

Output Parameters To Subproblem 6-06

vertical-spar-elastic-properties

Table 282. Design Relationships in Subproblem 7-51

vertical-rib-stresses-gust is a function of:

vertical-rib-deformations-gust
vertical-rib-elastic-properties

Table 283. Subproblem 7-51 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

vertical-rib-deformations-gust

Output Parameters To Subproblem 6-09

vertical-rib-deformations-gust

Table 283. Subproblem 7-51 Interfaces, cont.

Input Parameters To Subproblem 6-06

vertical-rib-elastic-properties

Output Parameters To Subproblem 6-06

vertical-rib-elastic-properties

Table 284. Design Relationships in Subproblem 7-52

vertical-stiffener-stresses-gust is a function of:

vertical-stiffener-deformations-gust
vertical-stiffener-elastic-properties

Table 285. Subproblem 7-52 Interfaces

PREDECESSORS

Input Parameters To Subproblem 6-09

vertical-stiffener-deformations-gust

Output Parameters To Subproblem 6-09

vertical-stiffener-deformations-gust

Input Parameters To Subproblem 6-06

vertical-stiffener-elastic-properties

Output Parameters To Subproblem 6-06

vertical-stiffener-elastic-properties

Table 286. Design Relationships in Subproblem 7-53

fuselage-aerodynamic-loads-turn is a function of:

maneuvering-3d-shape-turn

Table 287. Subproblem 7-53 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

fuselage-aerodynamic-loads-turn
maneuvering-3d-shape-turn

Table 288. Design Relationships in Subproblem 7-54

horizontal-aerodynamic-loads-turn is a function of:

maneuvering-3d-shape-turn

Table 289. Subproblem 7-54 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

horizontal-aerodynamic-loads-turn
maneuvering-3d-shape-turn

Table 290. Design Relationships in Subproblem 7-55.

vertical-aerodynamic-loads-turn is a function of:

maneuvering-3d-shape-turn

Table 291. Subproblem 7-55 Interfaces

PREDECESSORS

Output Parameters To Subproblem 6-06

vertical-aerodynamic-loads-turn
maneuvering-3d-shape-turn

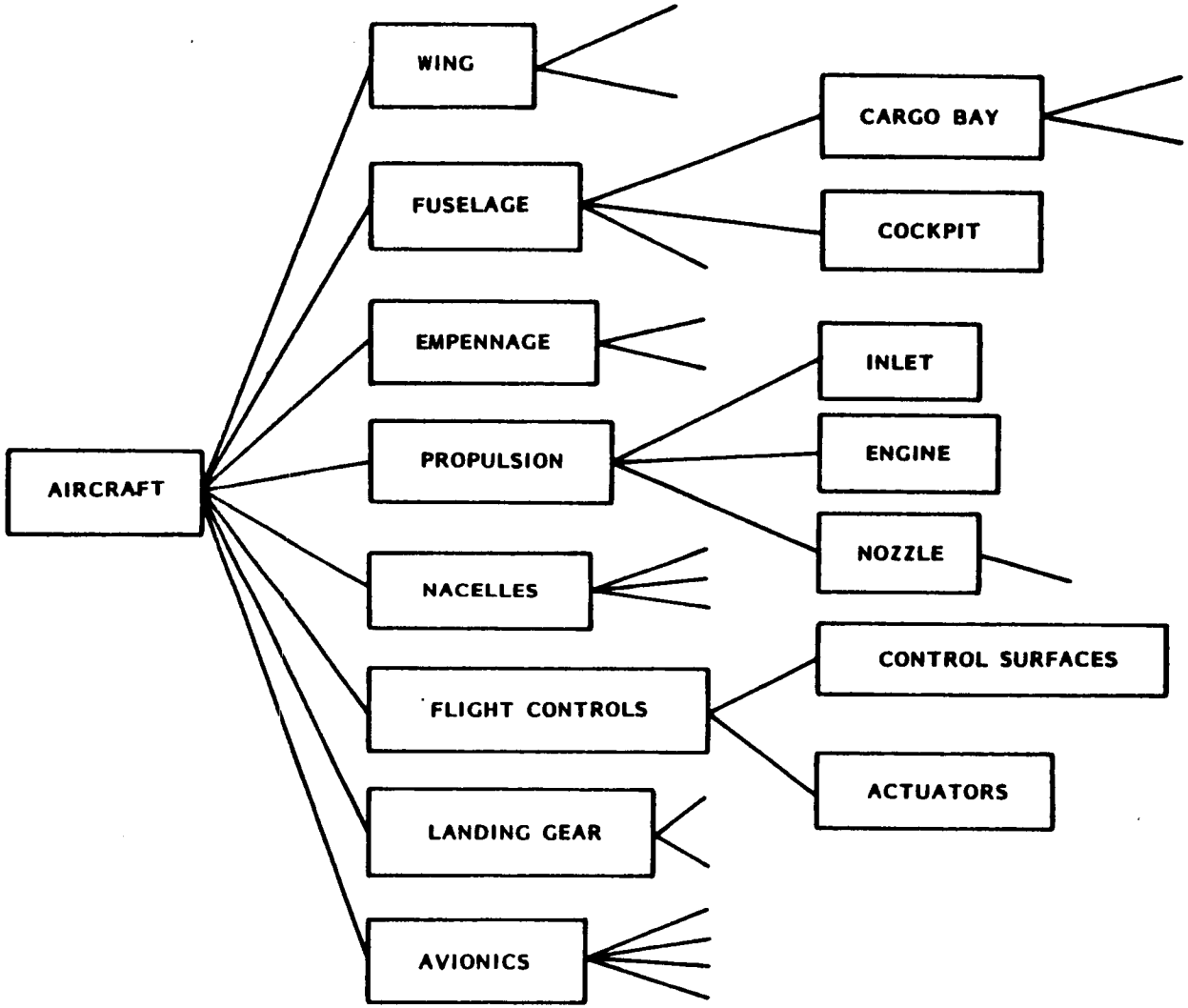

Figure 1. Part of the Aircraft Subsystem Decomposition.

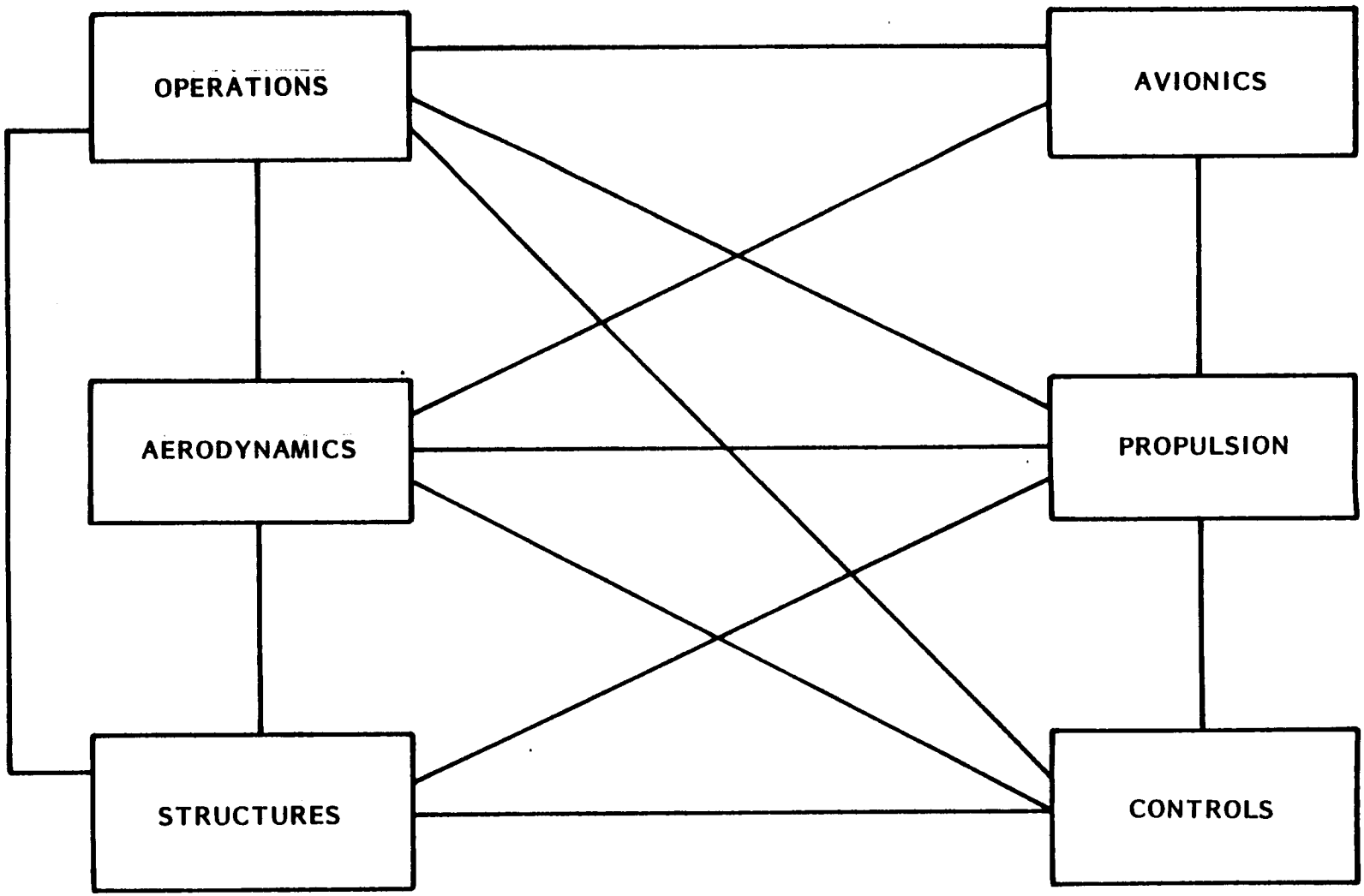

Figure 2. Part of the Aircraft Functional Decomposition.

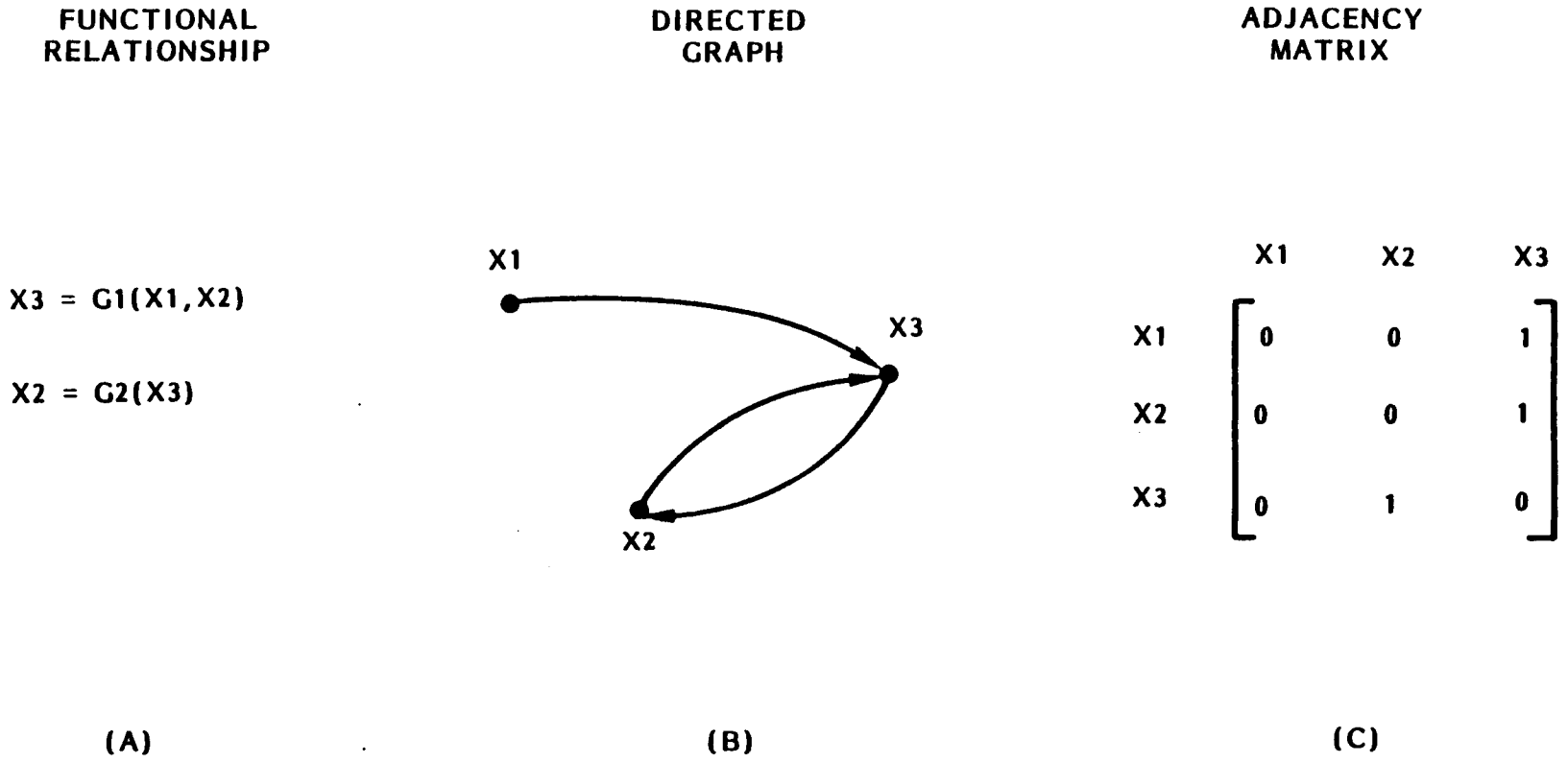

Figure 3. Representation of Functional Relationships.

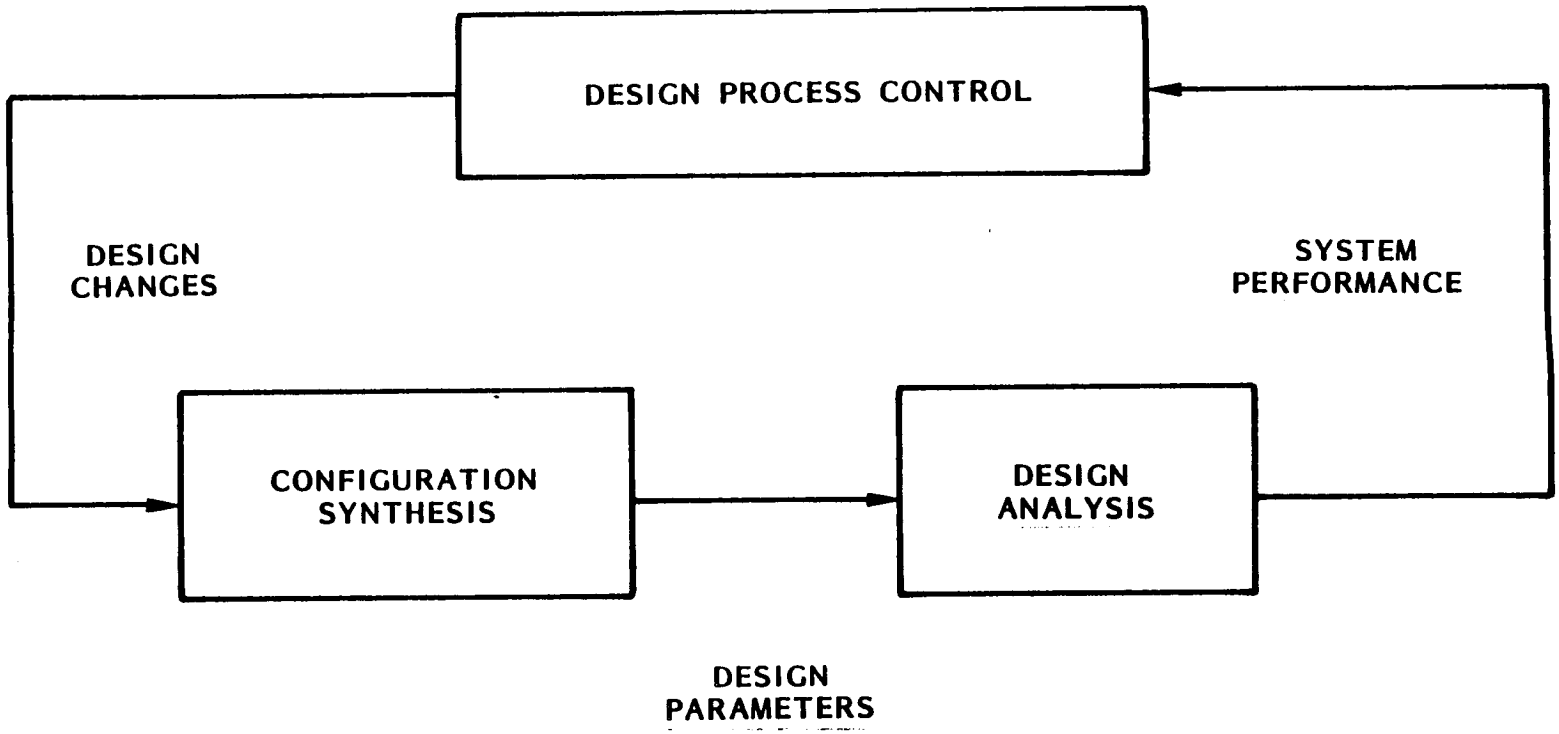

Figure 4. Design Optimization Model.

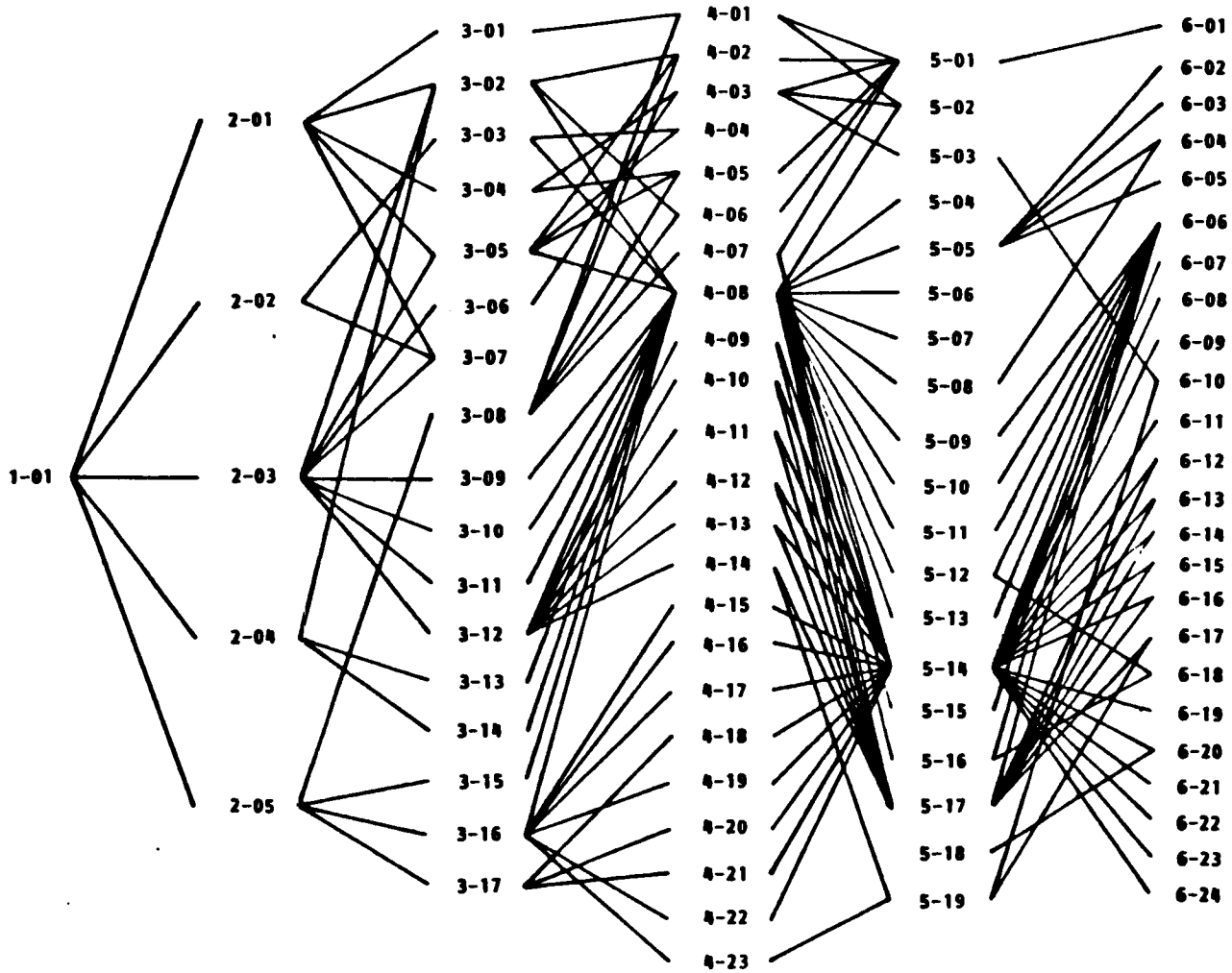

Figure 5 (a). Multifaceted Design Process Decomposition.

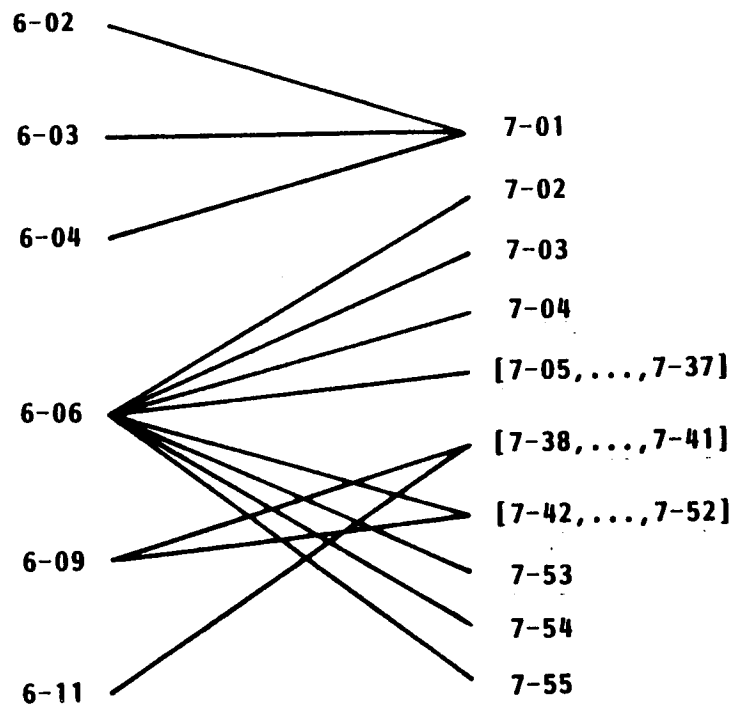

Figure 5 (b). Multifaceted Design Process Decomposition , (cont.).

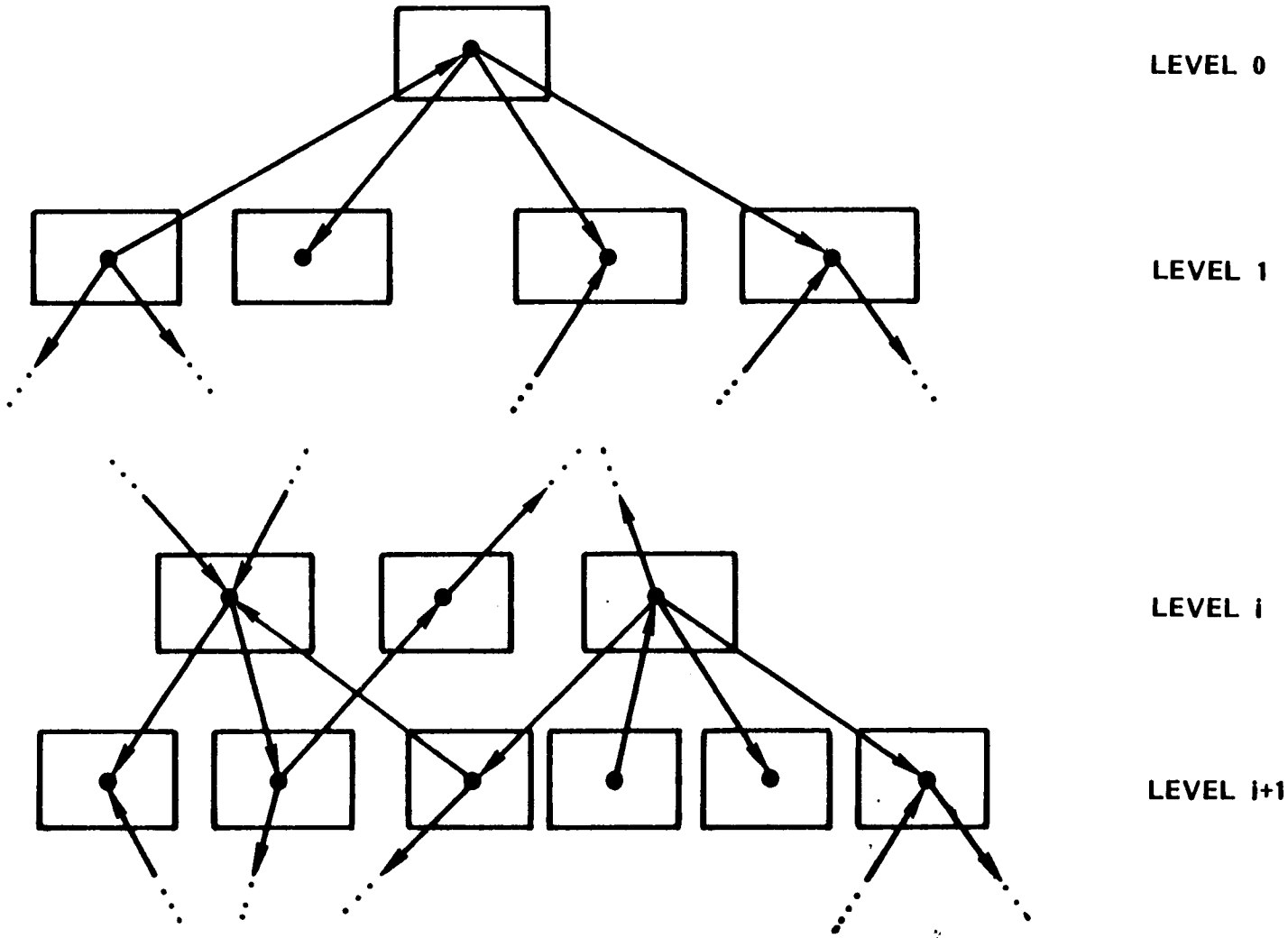

Figure 6. Heuristic for Finding Design Process Levels.

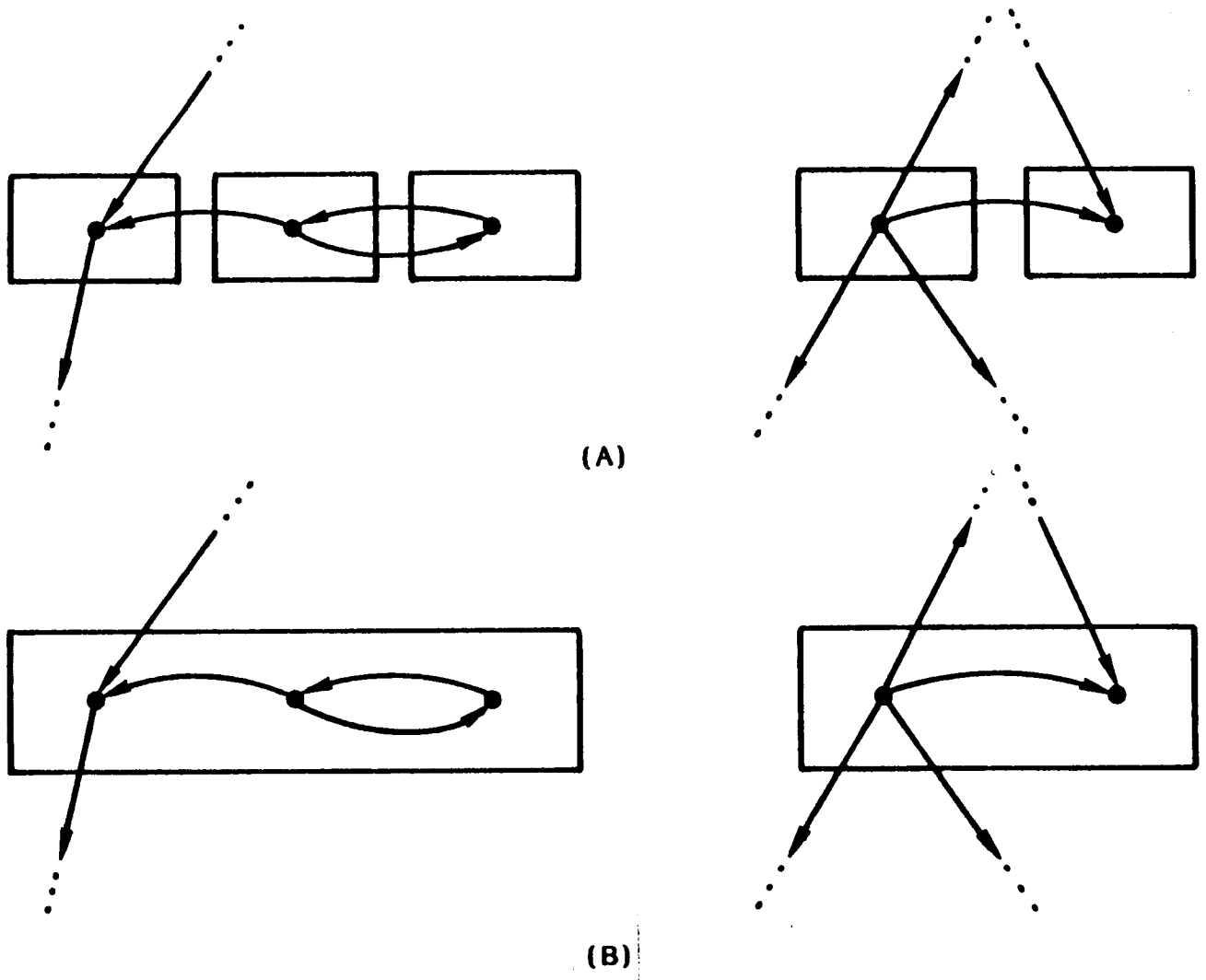

Figure 7. Heuristic for Eliminating Coupling within Levels.

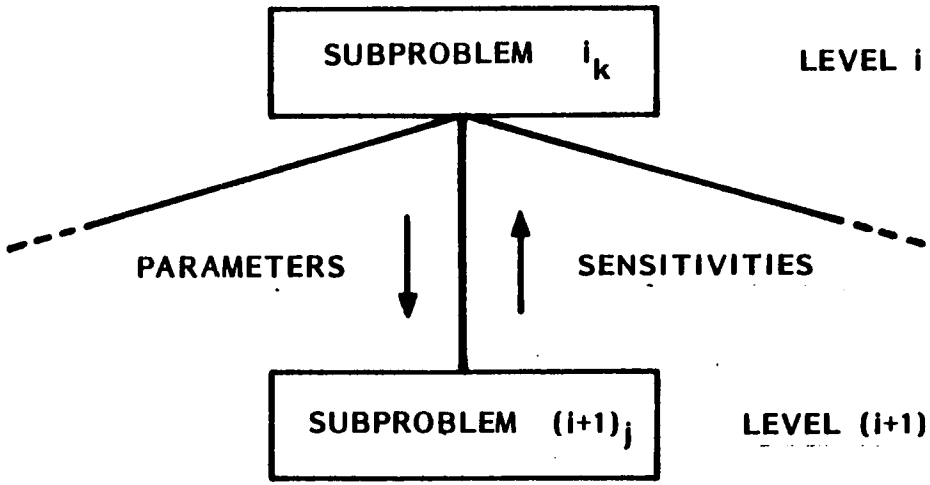

Figure 8. Iteration through the System Hierarchy.

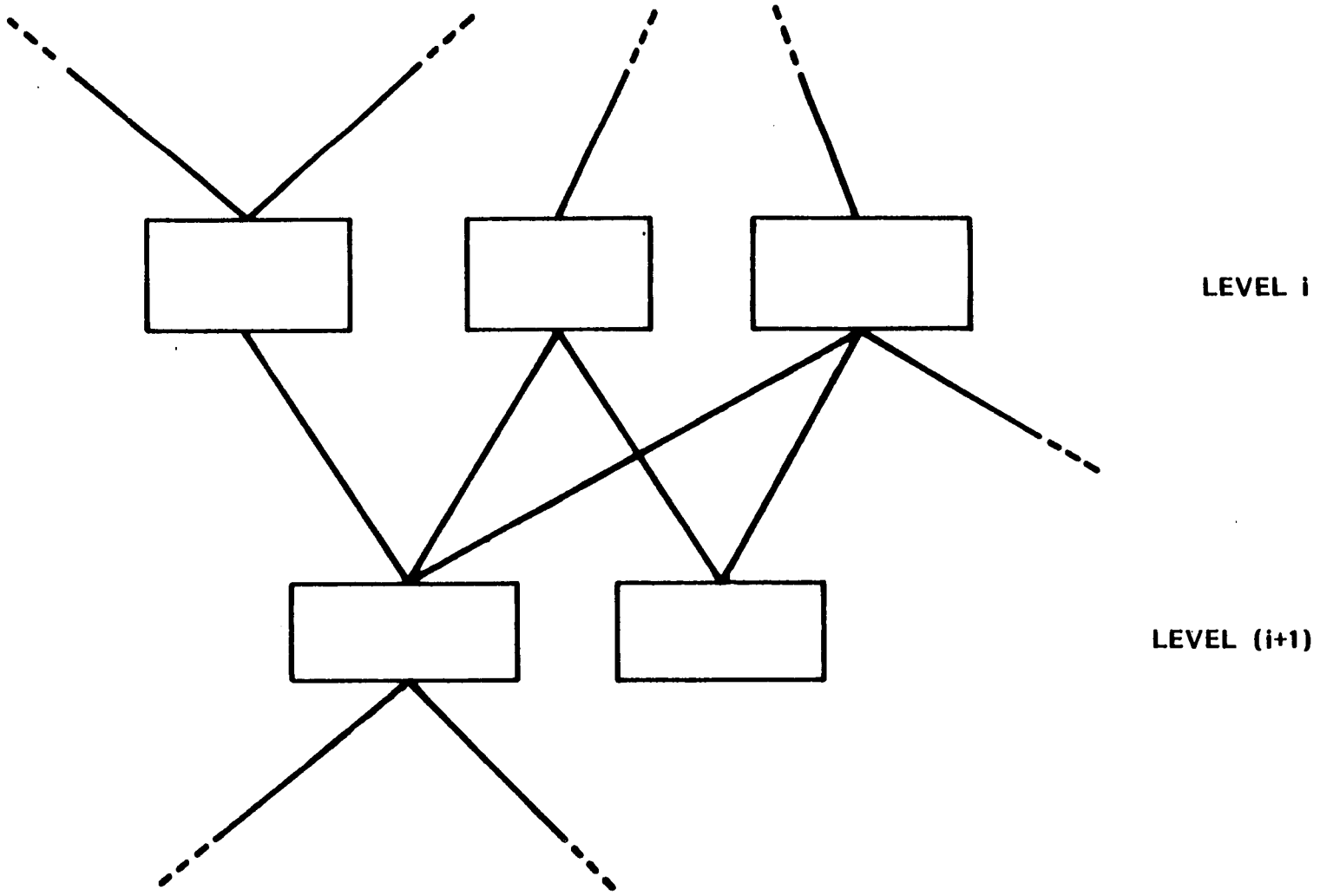

Figure 9. Form of the Multifaceted Decomposition.

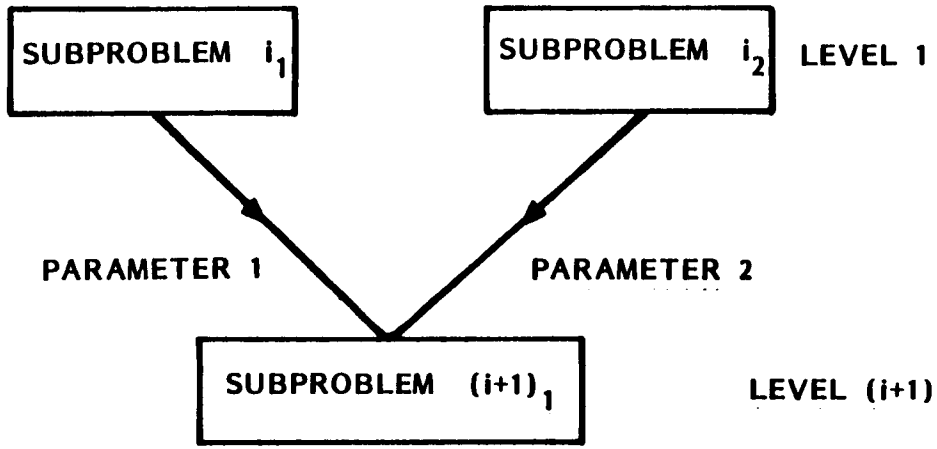

Figure 10. Subproblem with More than One Predecessor.

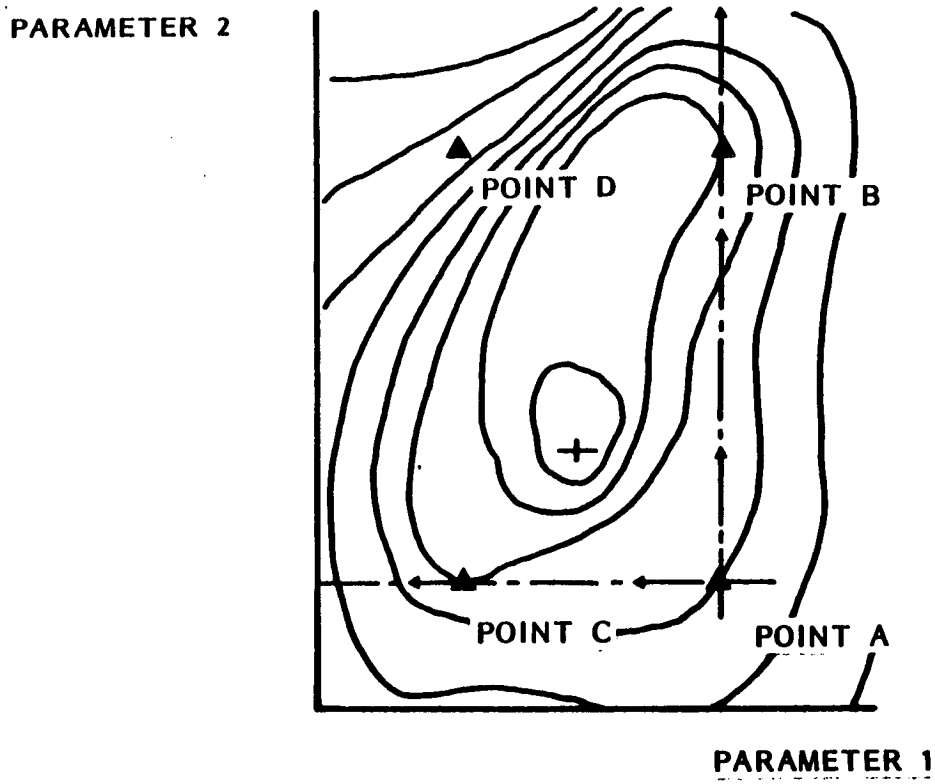

Figure 11. Divergence in the Multifaceted Decomposition.

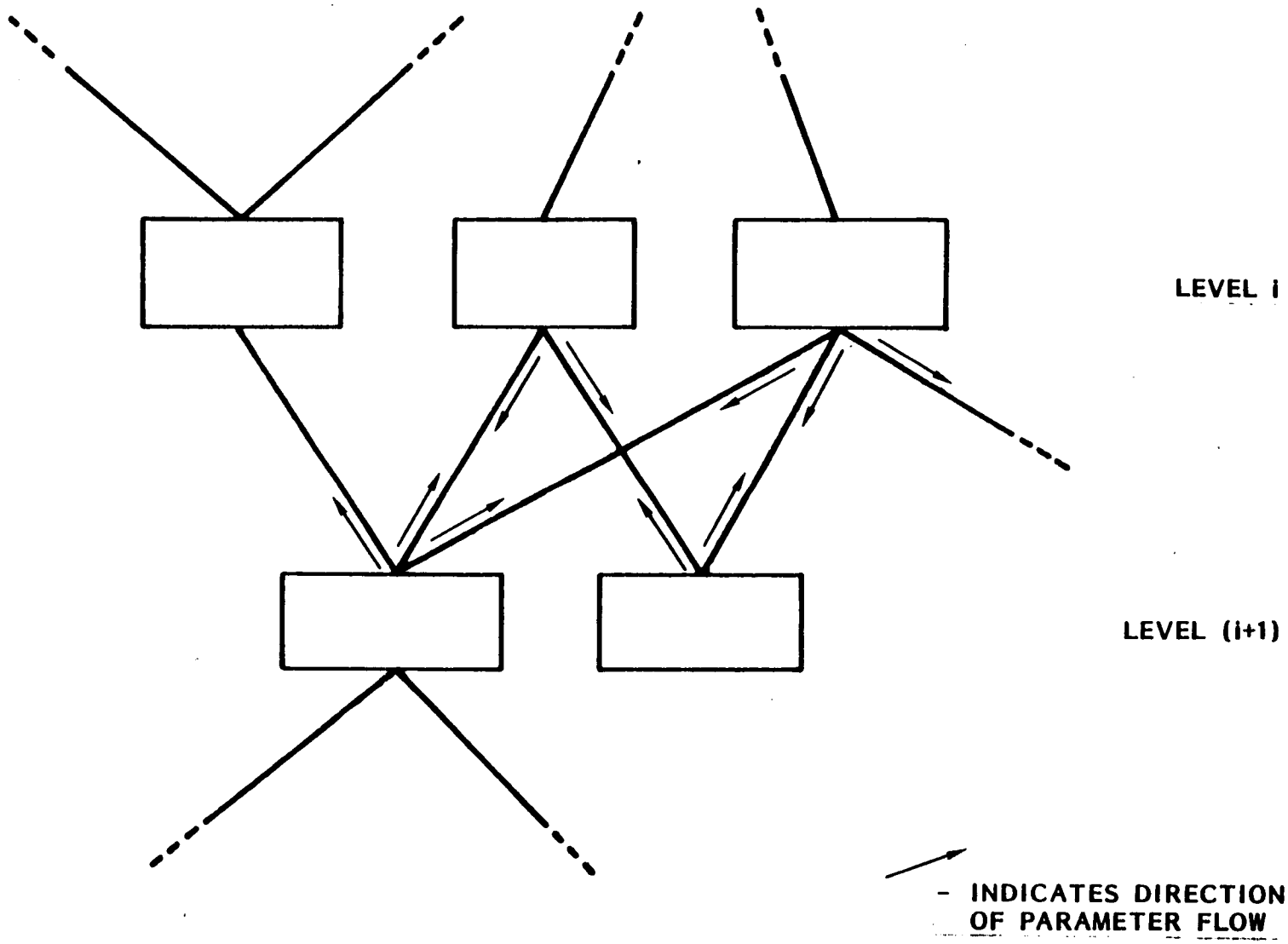

Figure 12. Proposed Iteration Procedure for the Multifaceted Decomposition.

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Final Report

16. Abstract

A nonlinear constrained optimization problem describing the preliminary design process for a transport aircraft has been formulated. A multifaceted decomposition of the optimization problem has been made. Flight dynamics, flexible aircraft loads and deformations, and preliminary structural design subproblems appear prominently in the decomposition. The use of design process decomposition for scheduling design projects, a new system integration approach to configuration control, and the application of object-centered programming to a new generation of design tools are discussed.

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